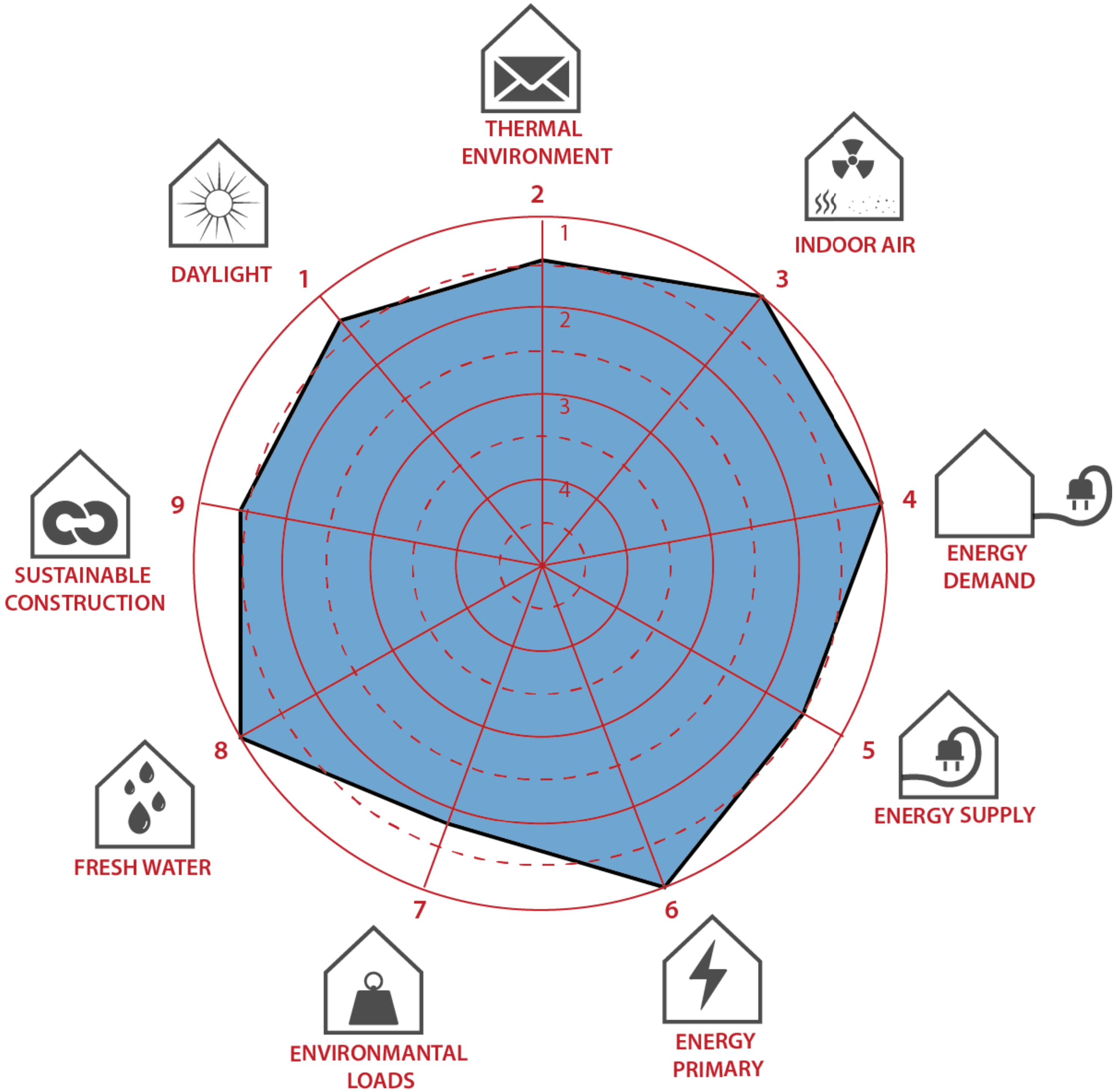
Master's thesis

APPLICATION OF THE ACTIVE HOUSE DESIGN PRINCIPLES ON FINNISH MULTISTOREY APARTMENT BUILDING.



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2020

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Aalto University-	Department of Architecture
Program-	Creative sustainability; master in architecture
Professorship -	Housing Design
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Title of thesis -	Application of the Active House design principles on Finnish multistorey apartment building.
Date -	10.11.2020.
Number of pages -	108
Presentation boards -	1 board

Abstract

The Active House Label is a recently developed certification method for buildings. Currently there are only approximately 100 buildings with an Active House Label, and most of them are in the EU and 0 in Finland. The Active House label presents itself as a simpler way of ensuring that buildings meet the current goals of Indoor Climate, Energy, and Environmental Impact.

Helsinki, the Capital of Finland, is one of the fastest-growing cities in the EU. The rapid growth of the City increases the demand for new apartments. Most of the apartment buildings constructed in the Helsinki region share similar design elements and special qualities. The growth in building industry requires that special consideration is given to the design and environmental impact of buildings that should last at least 50 years. This project investigates how the design of Finnish apartment buildings would differ if it would aim to meet the highest Active House standards.

In this work, the Active house certification tools and methods are used to determine typical Finnish multistorey apartment building's performance results. Results are compared with the apartment building that is designed to meet the highest Active house criteria. The apartment building designed in this project aims to achieve high performance using combination of architectural elements and passive strategies,

The apartment building`s design based on the Active House tools and manuals, illuminates weaknesses and strengths of this certification system. The architectural design of the new apartment building indicates elements and passive strategies that could be applied in other projects and indicates what can be expected. Active House analysis of the typical Finnish apartment building indicates expected quality in current development and areas of improvement.

This project illustrates the importance of the architect's involvement in a performance-driven design and suggests design directions that contemporary architecture might go towards.

DESIGN OBJECTIVES.

For several years I have pursued a robust design framework that incorporates Cradle to Cradle learning model, knowledge of the performance and properties of different building materials. I believe that Active House certification incorporates most of my design aspirations in one system without setting up too high criteria on some specific parameter, like, energy efficiency or environmental impact.

The focus of the Active House design is on three domains: the wellbeing of the occupants of the building, the environmental impact of the construction, and energy performance of the building.

A comfortable indoor temperature with clean, fresh air, and sufficient level of daylight are the main comfort parameters that are important to ensure the indoor comfort of the occupants of the building.

Environmental impact addresses not only the reduction of environmental loads but also the positive impact from the construction. This aspect entails the assessment of the life cycles of the construction materials, sustainable construction methods, and freshwater consumption. The environmental impact of the operation of the building often is a lot greater than the construction impact. Therefore, most certification systems focus on assessing the energy use, sustainable energy production and supply. Currently, it is possible to design and simulate all the variables required for assessing comfort, environmental impact, and energy. Implementing Active House certification allows us to make better design decisions, that can significantly improve the experience and life quality of the occupants of the building and create a positive environmental impact.

This study explores what changes could be implemented in Finnish architecture to follow Active House principles.

METHODOLOGY

In Finland most of the multistorey buildings share similar special qualities. To set up base line, one recent project that represents typical multistorey apartment building in Finland was selected. This project will be evaluated using the Active House Certification and will represent the qualities of a typical Finnish apartment building.

The program of the existing building will be respected and not changed (number of the apartments, size of the apartments, number of floors, and boundaries with surrounding properties). The new design of the building will search to improve the quality of the design in accordance with the requirements of the Active house label. The new design will search for improvements that will aim on reaching the highest score in every criterion evaluated in the Active House Label.

The selected, recently built, - multistorey apartment building (Base project) and design alterations done to meet and the Active house labels highest criteria (new Design) will be modeled in the Building Information Model using Autodesk software Revit 2020. The geometry of the building and the collected information will help run the performance analysis. The Active House alliance provides an evaluation tool and suggests workflows for generating the input values that allow users to create the Active House Radar – a Chart indicating the Active House performance in different design areas. This chart indicates the building`s performance level and conformity with the Active House Label.

Daylight analysis is the first focus area in the Active House software, version 1_07. The Velux daylight visualizer 2nd version is recommended by the Active House alliance and will be used in calculating the Daylight Factor. The Active House Alliance provides tools for calculating thermal comfort. The Indoor air quality level influences the energy demand for the ventilation system. The Passive house calculation tool, PHPP version 8.5 is used to calculate the total energy demand for the building (including the energy use for the ventilation system). The energy supply calculation is done by hand and verified with the Photovoltaic Geographical Information System (PVGIS) tool. For the calculation of environmental load and sustainable construction, the Active House alliance has provided the Life cycle analysis tool. At first for the calculations the 1.4 version was used and later when the newest version came out, the calculations were redone using the 1.5 version. For the freshwater consumption calculations, the Active House has provided the Freshwater consumption tool.

To improve the performance of the building in the Active House Radar chart and meet the Active House Label standards, the building will be redesigned using the tools suggested by the Active House Alliance. The Daylight Factor has the most significant influence on the design of the building. To meet the Active House criteria, it is necessary to repeatedly alter several parameters of the building. To automatize this process the design software Rhino with scripting software Grasshopper and multiple plugins like ladybug and honeybee will be used. All the above-mentioned software will be used to improve the design of the building and meet the demands of the Active House Label.

CONTENTS

1 THE NEED FOR A NEW APPROACH IN THE BUILDING INDUSTRY

In the last 100 years human activities on this planet have left a noticeable environmental impact, that has influence on climate, natural resources, biodiversity, and air quality. The Paris Agreement signed by the majority of the countries in the world in 2016 recognize the importance of the reducing emission caused by human activity. The Paris Agreement sets a goal to keep the global average temperature increase below 2° C from pre-industrial times. To meet this goal, global CO2 emissions and energy use should be reduced.

The international scientific community is increasingly recognizing the risks of global warming. In an attempt to reduce the negative impact of environmental changes, the global community is striving to reduce environmentally unsustainable practices. In the past decades there have been several major international treaties (Vienna Convention 1985, Montreal Protocol 1987, UNFCCC Framework Convention 1992, Kyoto Protocol 1997, Paris Agreement 2015) and a multitude of smaller scale agreements. The Paris Agreement concluded with 189 parties agreeing to contribute towards the reduction of emissions and energy use. However, The Agreement did not set out a strategy for reaching the goals. At the moment most of the goals for environmentally sustainable practices have not been reached in most countries. Therefore, we must search for new areas of human activity that can be changed to reduce pollution and energy use.

1.1 GLOBAL WARMING

Global human population has had a steady rise from 2,6 billion in the year 1950 to 7.7 billion in the year 2020[1]. With the increasing number of people, we are facing an increase in pollution from human activities and global energy demand. Even though appliances and services are less energy-intensive than 100 years ago, our environmental footprint is growing alongside our demand for new products, appliances, transportation, and housing.

[1] United Nations https://www.un.org/en/sections/issues-depth/population/index.html

Global warming brings many challenges and areas that will need to be addressed in near future. Many scientists believe that our planet is about to enter a new stable state that we have not experienced before, and no one can predict the possible outcomes of this process (Figure 1 illustration). We can only guess what the future holds from the current climatic changes in nature – ice caps melting, global temperatures rising, wildfires, the loss of biodiversity. There is a strong belief in the scientific community that human interference in the complex systems of our planet, and misuse of natural resources are leading towards dangerous environmental depletion. Irreversible human-caused planetary changes most likely are about to radically change the climate and available recourses. Already in Europe, we are experiencing record-breaking high and low temperatures[2] , and in some parts of Asia, copper mining has moved from mines to landfills.

Human activities on this planet are not leaving a positive environmental impact. The life of a Contemporary person is directly connected with pollution. Ranging from small activities such as extensive use of energy, consumption of consumer goods and packaging, eating meat, to large scale activities, such as extensive traveling, misuse of finite natural resources and real estate development. Nevertheless, we as a society carry on with our lives without implementing major changes. I believe that people can make a positive impact on the environment if they are given the choice and tools that allow them to do so.

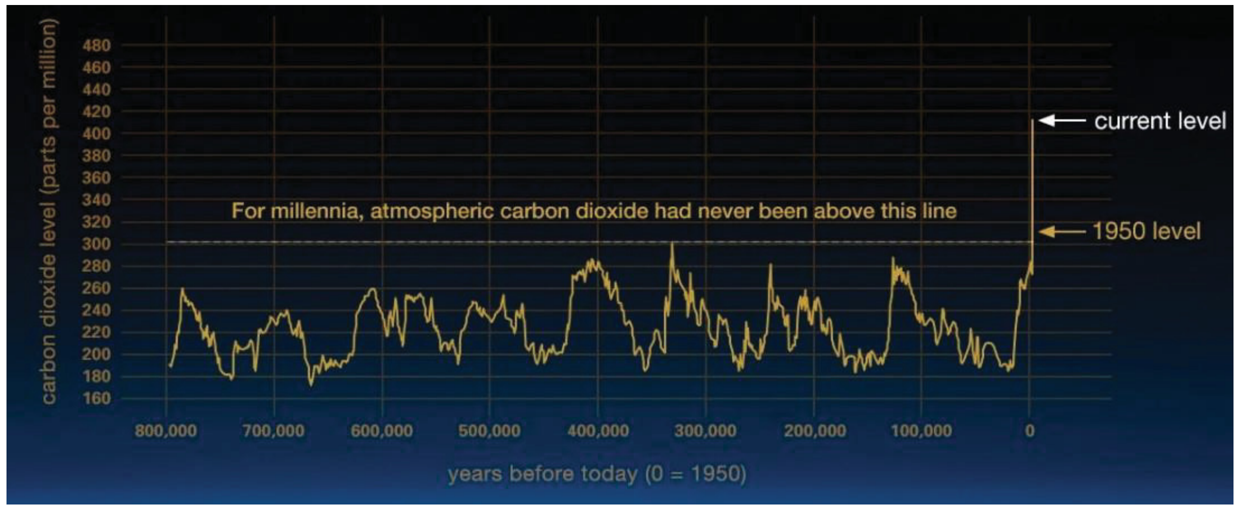
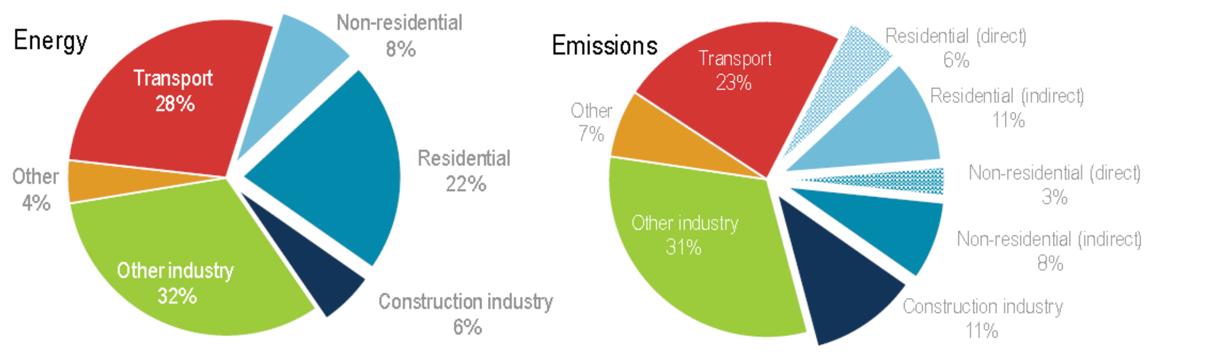


Figure 1 Atmospheric CO2 https://climate.nasa.gov/evidence/

[2] Climate change service homepage Link - https://climate.copernicus.eu/record-breaking-temperatures-june

1.2 BUILT INDUSTRY – BIGGEST POLLUTERS

It is paramount for Built Industry design principles to be guided by consideration for environmental impact alongside consumer satisfaction. Buildings need to prioritize energy-efficiency alongside comfort to improve the surrounding environment and drive us towards a sustainable future. Currently Construction industry accounts for approximately 39 % of GHG emissions, 36 % for final energy use and 35 % of material use[3]. Future projections show an increased demand for housing with some sources suggesting that in the next 40 years construction industry will have to build as much as humanity has built up until this moment. The building and construction sector should be the primary target for GHG emissions mitigation efforts, as it accounted for 36% of final energy use and 39% of energy- and process-related emissions in 2018. [4]



Notes: *Construction industry* is the portion (estimated) of overall industry devoted to manufacturing building construction materials such as steel, cement and glass. Indirect emissions are emissions from power generation for electricity and commercial heat.

Figure 2 Global share of buildings and construction final energy and emissions, https://www.worldgbc.org/news-media/2019-global-status-report-buildings-and-construction#:~:text=The%202019%20Global%20Status%20Report%20for%20Buildings%20and%20Construction%20releas

With growing population and the increasing floor area, the data over the last few years shows a 1% increase in energy consumption and a 2% increase of global emissions annually, since 2010. This data indicates that there should be radical change in building sector if we even hope to meet the goals of the Paris Agreement[5] and the 2030 climate & energy framework[6]. To meet the 2030 climate and energy framework, (40 % greenhouse gas emission reduction cuts from year 1990 levels) we must reduce global emissions by 7.6 %[7]annually starting year 2020.

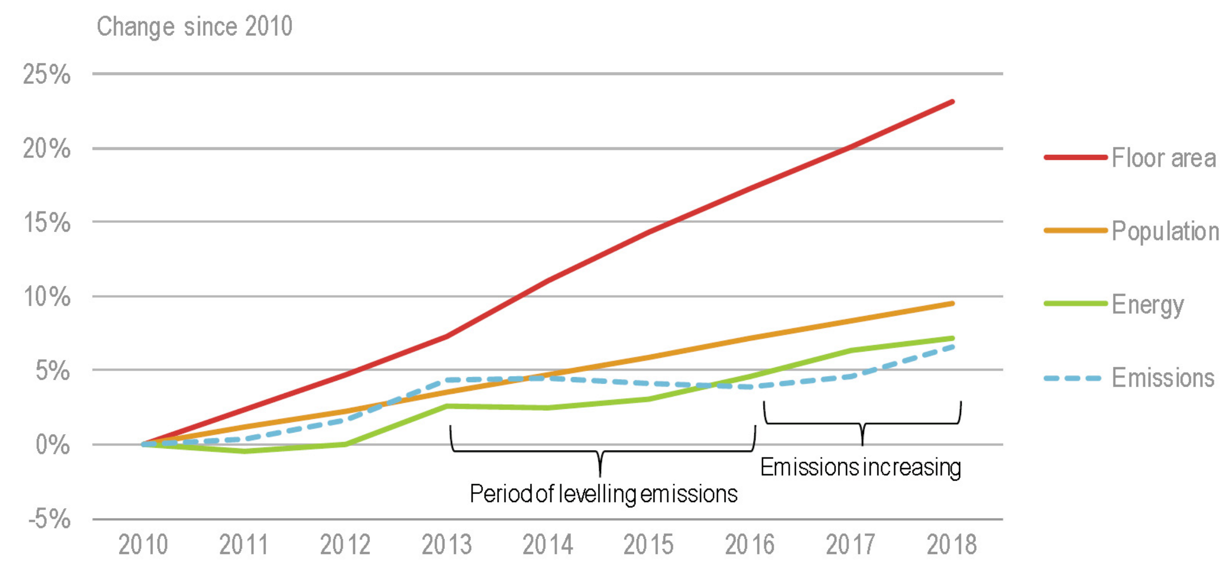


Figure 3 Changes in floor area, population, buildings sector energy use and energy-related emissions globally, 2010-18 Source: Derived from IEA (2019a), World Energy Statistics and Balances 2019, www.iea.org/statistics and IEA (2019b) Energy Technology Perspectives, buildings model, www.iea.org/buildings

1.3 BUILDINGS AND THE CONSTRUCTION INDUSTRY – PART OF THE SOLUTION.

According with the World green building council`s 2019 Global status report for buildings and construction, buildings and construction sector is the greatest polluter. Greenhouse gas emissions are correlated with negative environmental impact. The report also presents a positive future scenario. Considering that the direct and indirect emissions in the building and construction sector from residential and non-residential construction accounts in total for 39 %, it presents one area of global emissions that could be a big part of the sustainability solutions.

[3] Merrild, H, Guldager Jensen , K & Sommer , J 2018, *Building a Circular Future*. vol. 248 , 3 edn, GXN , Denmark http://grafisk.3xn.dk/CAC/BuildingACircularFuture_3ed.pdf

[4] The 2019 Global Status Report for buildings and construction, Worlds green building council, Page12 https://www.worldgbc.org/news-media/2019-global-status-report-buildings-and-construction#:~:text=The%202019%20Global%20Status%20Report%20for%20Buildings%20and%20Construction%20released,cent%20of%20total%20carbon%20dioxide

[5] https://ec.europa.eu/clima/policies/international/negotiations/paris_en

[6] https://ec.europa.eu/clima/policies/strategies/2030_en

[7] https://unfccc.int/news/cut-global-emissions-by-76-percent-every-year-for-next-decade-to-meet-15degc-paris-target-un-report

By rethinking and redesigning the building industry, we could greatly reduce the global emissions.

In the last decade there have been steady improvements in energy efficiency in the building industry. Due to technological improvements, overall reductions have been made in energy intensity for space heating, lighting, appliances, cooking and water heating[8]. However, the current high hot season temperatures present a new challenge with an increased energy use for cooling. In Northern Europe a new residential building most likely will have some sort of a heating system in place, but lately cooling systems start to appear in these buildings as well. Multiple climate analysis and design tools are offering passive cooling strategies that could eliminate air conditioning systems in building, therefore creating energy savings just by modifying the design of the building.

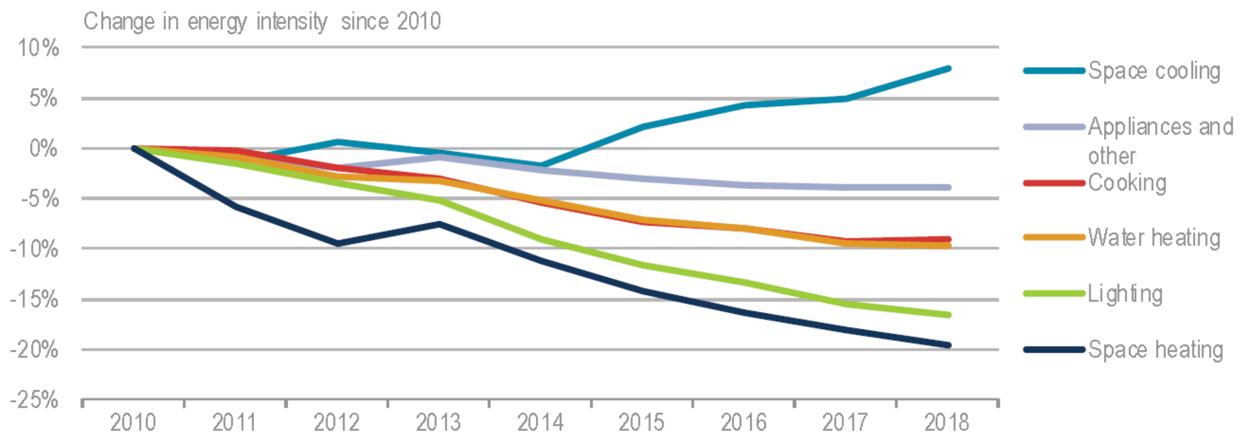


Figure 4 Global buildings sector final energy intensity changes by end use on1 m2 floor area, 2010-18, https://www.worldgbc.org/news-media/2019-global-status-report-buildings-and-construction#:~:text=The%202019%20Global%20Status%20Report%20for%20Buildings%20and%20Construction%20released,cent%20of%20total%20carbon%20dioxide

In most cases the greatest hindrance for a swift adoption of environmental solutions is the increased financial cost. Therefore, I believe that there is a great need for increase in governmental initiatives aimed at stimulating the environmentally beneficial buildings, resembling the current initiatives supporting electric cars. The design expenses for new constructions usually range between 6-10 % of the construction costs. Implementation of environmentally beneficial strategies increases the design and construction expenses. However, the environmental benefits and long-term savings of implementing environmentally beneficial strategies could outweigh the costs, presenting a strong financial incentive.[9] For example, 3xn architects present a method for measuring potential financial savings by designing for disassembly. In a case study they present financial benefits of reusing superstructures of office buildings.[10]

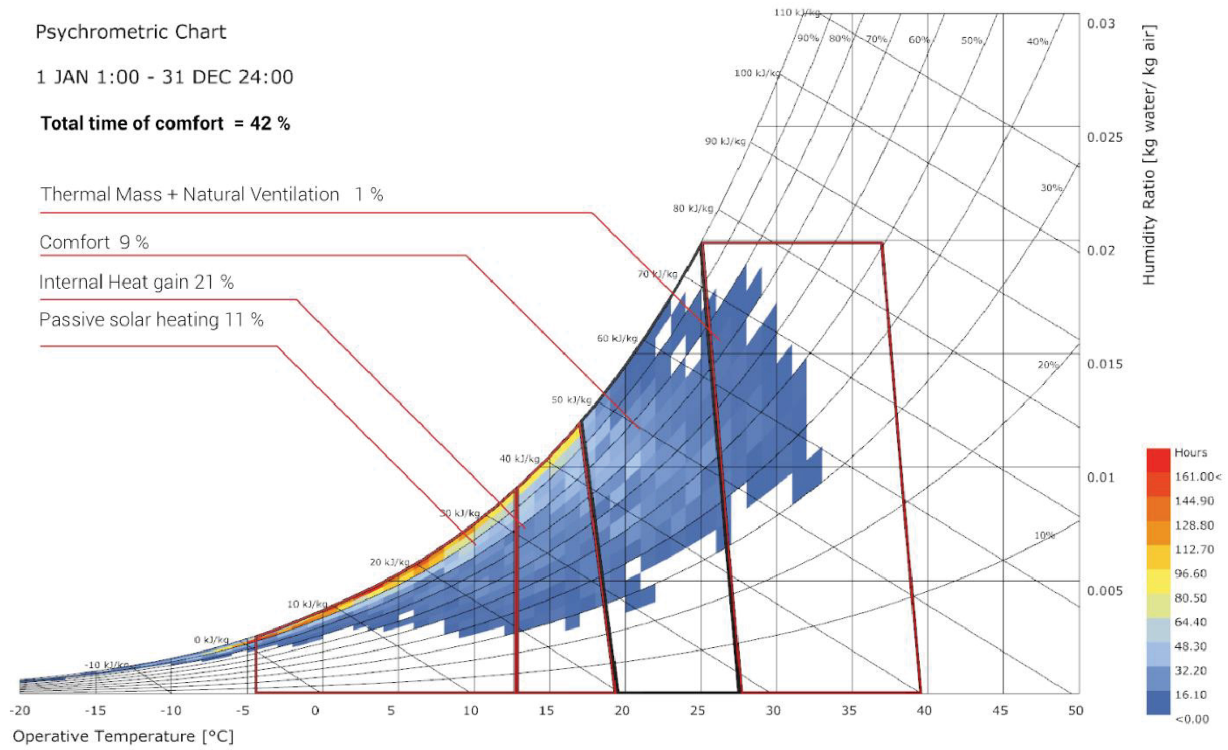


Figure 5 Psychrometric chart of thermal comfort in Helsinki, Finland

[8] The 2019 Global Status Report for buildings and construction, Worlds green building council, Page14 https://www.worldgbc.org/news-media/2019-global-status-report-buildings-and-construction#:~:text=The%202019%20Global%20Status%20Report%20for%20Buildings%20and%20Construction%20released,cent%20of%20total%20carbon%20dioxide

[9] Merrild, H, Guldager Jensen , K & Sommer , J 2016, Building a Circular Future. vol. 248 , 1 edn, GXN , Denmark . <http://issuu.com/3xnarchitects/docs/buildingacircularfuture/283?e=5740644/35968611>

[10] Merrild, H, Guldager Jensen , K & Sommer , J 2019, Building a Circular Future. vol. 248 , 3 edn, GXN , Denmark page 220 to 246

1.3.1 Certification methods.

The first green building rating system, Building Research Establishment's Environmental Assessment Method (BREEAM) was launched in year 1990. With this system the performance of buildings is measured in 9 different categories: Management, Health & Well-being, Energy, Transport, Water, Materials, Waste, Land Use& Ecology, Pollution. BREEAM certification system is widely adopted across the globe, used in 80 countries and more than 565 000 issued certificates, and has served as the basis for many other certification systems such as LEED and Green Globe. [11]

It is estimated that currently there are over 600 building certification systems. Some of them are tailored for specific type of buildings, regions, or have differently divided, prioritized categories of performance measurements. Generally, all certification systems target reduction of emissions and energy use while improving the health and life quality of the occupants of these buildings. Certification systems vary in what categories are assessed for measuring the performance of the building, and what procedures they use.

1.3.2 Green Building Rating And Certification Systems

The Green Building Rating and Certification System is relying on the Building standards and the Green Product Certification. Building standards are regularly updated, enforcing stricter requirements in new construction and renovations. This improves the energy efficiency and indoor climate. Green Building Rating and Certification Systems often will require a higher level than the building standard to improve the rating of the building.

All buildings are a combination of multiple materials and products. Therefore, it is challenging to estimate the actual environmental and health impact of a construction when taking into account all materials and products used in the building. Environmental Product Declaration (EPD) is a document that provides comparable information about the environmental impact during the lifecycle of the product. While EPD provides a comparative information of the product, green product certifications are ensuring that the selected product will meet certain standards and offer environmental benefits. In Europe most popular are Forest Stewardship Council (FSC), Cradle to Cradle (C2C) Green product certifications.

The primary reason for the creation of rating systems is the need to clearly define, implement, and measure the Green Strategies and their outcomes and impact. The rating system guidelines enable optimal implementation of Green Product Certifications. There is a great variety of green products and materials. Rating systems outline, what Green Standards need to be followed, and what types of green products should be included in construction. Selecting the correct certification system gives guidelines to the project and informs the design.

Active House certification has not yet been used in Finland. This project illustrates the potential of this certification. Active House offers a vision of buildings that create healthier and more comfortable lives for their occupants without the negative impact on the climate, moving building industry towards a cleaner, healthier, and safer practices. Food, shelter, and community are primary needs for healthy human life; and a good housing project provides the opportunity to encapsulate all these needs.

The Active House Label differs from other certification methods with accessible, easy to use tools for calculating certification criteria and a low price of certification. During the certification process, each building is evaluated i according to 9 principles. The Active House Specification offers more than 40 other qualitative criteria that are used to guide the design process, but do not influence the calculated performance of the building.

[11] https://www.wbdg.org/resources/living-regenerative-and-adaptive-buildings

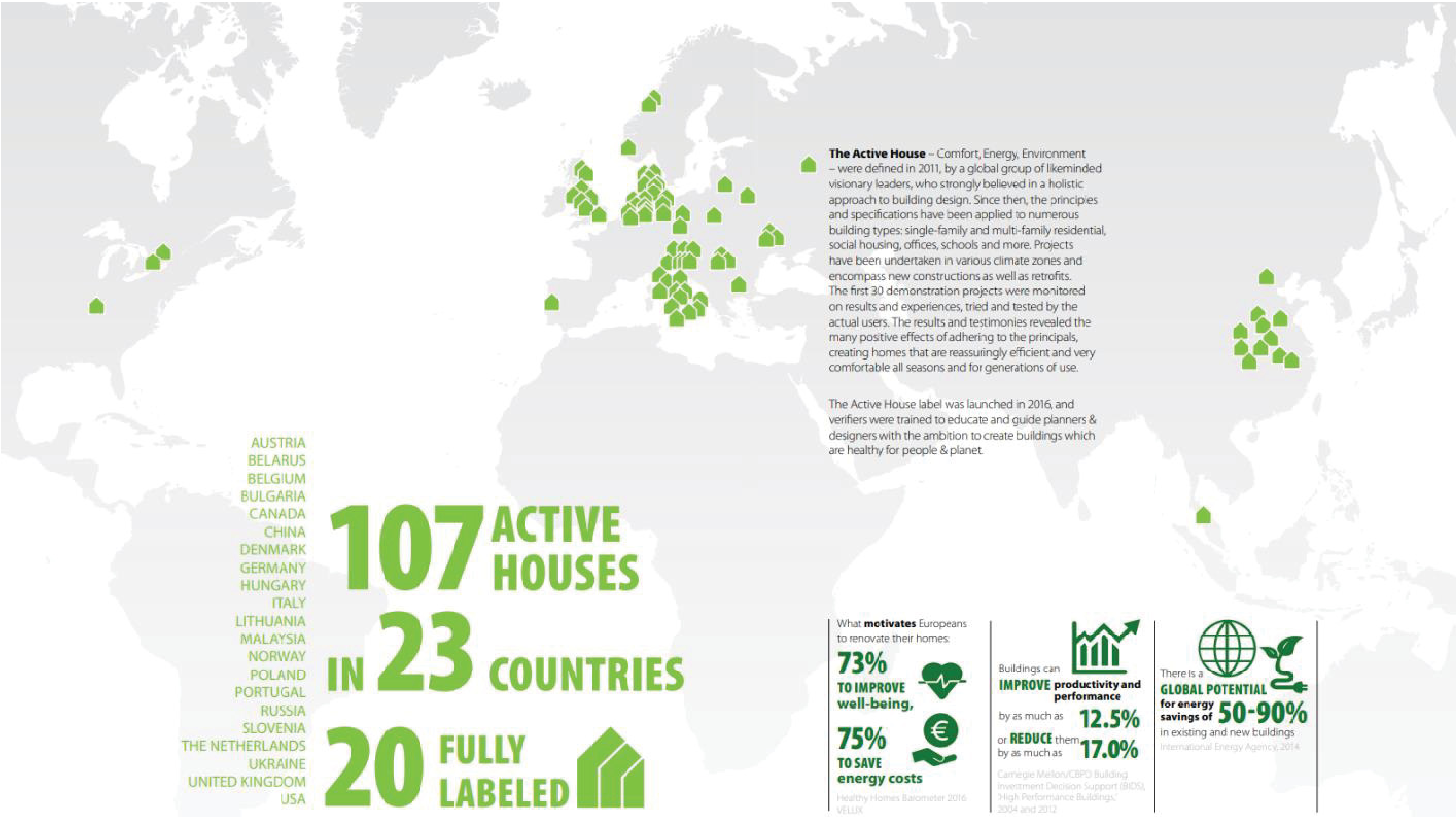


Figure 6 Active house map 2020, source Active house guidelines, https://www.activehouse.info/submit-your-project/create-a-radar/

The Active House certification proposes a target framework for how to design and renovate buildings that contribute positively to human health and well-being. It focuses on the indoor and outdoor environment and the use of renewable energy. An Active House is evaluated based on the interaction between 3 focus areas: energy consumption, indoor climate conditions, and impact on the environment. Each focus area is divided into 3 parts: comfort, energy and environment. Comfort focus area is evaluated by assessing daylight, thermal environment, and indoor air quality. The energy focus area is divided into energy demand, energy supply, and primary energy categories. Environmental focus area is evaluated by assessing environmental loads, freshwater consumption, and sustainable construction.

There are 9 Design principles set in the Active House Certification. During the process of design and evaluation, these nine criteria are graded. Each of them sets a requirement for a minimal quality level in order to receive the Active House Certification. There is only one level of certification- either the building receives the Active House Label, or it does not.

1.4 Why Active House principles

The Active House Certification relies on similar principles as other widely used certification systems, such as LEED and BREAM. The difference is that this certification method is well described, it has fewer criteria, it is based on partnerships, it is popular in the EU, it offers free calculation tools, and it is cheaper to get the building certified.

The Active House Rating System has a very simple design. The rating system consists of three focus areas that are subdivided into three criteria, in total, nine criteria. Each criterion receives a rating from 0-5 depending on the calculated values. As a result, if the building gets a rating in all nine criteria, it receives the Active House label. The criteria for certification are less specific, helping to address general, important points. The less important points are mentioned in the certification checklist. LEED, on the other hand, includes 45 criteria and a possible total score of 110. Depending on the score a building receives a LEED certification level - silver, gold, or platinum. The objective of the Active House Certification system is to improve and guide the design process of the building, as opposed to encouraging rating-based competition between the developers.

There are many LEED or BREAM certified buildings in the EU. These certification systems are the most popular in the EU but were designed for buildings in the USA. The Active House Certification was designed in the EU and mainly focuses on residential buildings in the EU context. Furthermore, lower price for certification encourages the use of the Active House Certification in private residential buildings while LEED and BREAM are mostly used in commercial buildings.

In the Active House homepage www.activehouse.info one can find guidelines and specifications of the method, criteria used for rating, as well as free-to-use software for calculating freshwater consumption, environmental loads, Thermal Environment, and the main program where all calculated data is collected to make an Active House Radar chart. The information that is provided and the free webinars organized regularly make this certification method more accessible than others.

Figure 7 : Active House Radar, source Active house guidelines_version_1, https://www.activehouse.info/submit-your-project/create-a-radar/

1.4.1 Examples of projects (inspiration). Active House

One of the main areas of research in architecture is the study of people and their way of living reflected in building practices. Built environments hold great responsibility with their long lifecycle, vast investment and lengthy design and built process. Therefore, it is important to learn from the work done by others, gaining inspiration and ideas that could be reproduced.

As mentioned in section 1.2 Built industry – biggest polluters – the biggest polluters are not only a part of the problem but has the potential for creating a positive change. Bill Red with his design approach, 3xn design approach, and Cradle to Cradle has illustrated that the built environment could be a part of the solution during the climate change crisis. Architectural companies like 3xn, and Regenesis group with Bill Reed and William McDonough + Partners have projects designed around Cradle to Cradle (C2C) principles and Regenerative Architecture. They take into the account the need for minimizing the carbon impact on the environment, and strive towards maximizing the positive environmental, social, and economic aspects. They propose to move from linear to a circular design model, designing with materials and making products in a closed-loop system that positively contributes to the environment. Cradle to Cradle concept of closed loops suggest design that gives ability of repeatedly using products, in this case building components like concrete and steel elements, and reusing materials without losing the quality of the materials. Currently, only a few multistorey residential housing projects take these principles into the account.

Considering all the available data and the current patterns regarding the environmental changes, we need to rethink the way we build and inhabit cities. With the current knowledge, tools, and technological advancements, we can design a better built environment. We can design buildings that are healthy, safe, affordable, and environmentally friendly, designed to fully use the whole life cycles of the materials with a possibility to change functions and layouts, designed to be disassembled and reassembled in different configurations or moved to completely other location. Buildings that agree with climate and local conditions and sequent more carbon dioxide than pollute during their lifecycle. Some of the good examples are Green solution House in Denmark design by 3XN and B/S/H in the Netherlands designed by William McDonough + Partner.

Visualisation: Circle House demonstrator.

Visualisation © GXN

Figure 8 Circle House demonstrator Visualization by GXN architects, https://gxn.3xn.com/project/circle-house-demonstrator

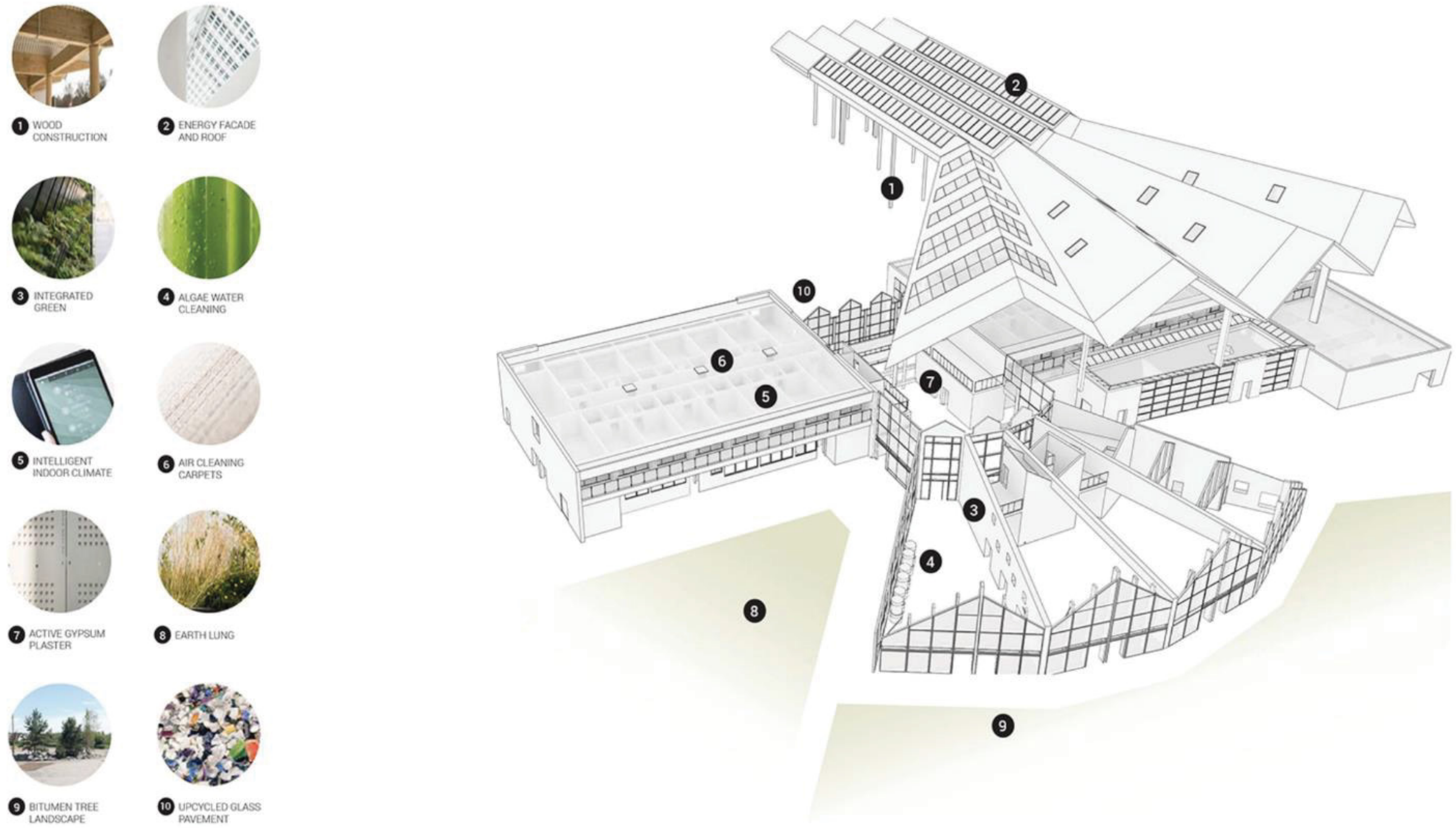


Figure 9 Green solution house by 3XN architects, https://gxn.3xn.com/project/green-solution-house

Green solution house is a Conference center and hotel designed following Cradle to Cradle (C2C) principles- all materials used in the construction are recyclable or biodegradable. The building, designed on the Danish island Bornholm in city Ronne, functions as a process in a closed-loop that eliminates waste. Solar cells produce all the energy for the building, rainwater is collected and used in the building, wastewater is biologically cleaned and reused in the crop fields. Most of products used in restaurant kitchen come from local field or buildings greenhouse reducing energy use on product delivery.[12] [13]

[12] https://www.greensolutionhouse.dk/en/green-solutions-2/
[13] https://gxn.3xn.com/project/green-solution-house

Figure 10 The Bosch Siemens Headquarters in Hoofddorp, NL, [*https://mcdonoughpartners.com/projects/bsh-office-the-inspiration-house-at-park-2020/*](https://mcdonoughpartners.com/projects/bsh-office-the-inspiration-house-at-park-2020/)

The Bosch Siemens Headquarters in Hoofddorp, NL, built in 2011 was the first building completed in Park 20 | 20 – Cradle to Cradle inspired development. The design of the building encourages collaborative work, it integrates interesting designs for public areas that are well lit by daylight. The building was entirely designed from C2C certified materials meant for disassembly. A unique design of Slimline composite floor slabs allows to avoid suspended ceilings, it makes the construction lighter and reusable. Slimline composite floors are made from Steel beams and a thin layer of concrete, creating hollow construction that gives space for building service installations. This construction could be disassembled and reused in the construction of a new building.[14] [15]

[14] https://www.deltadevelopment.eu/en/projectdevelopment/bsh/
[15] https://www.slimlinebuildings.com/slimline-concept.php

The Circle house project, designed by 3XN, consists of 60 social housing units, covering around 5500 m2 of floor area. All units will be built using circular economic principles. The building will be designed for disassembly and reuse. 90 % of the materials could be recycled in the future without losing value. Before the construction of the Circle house, a demo house in Copenhagen, Denmark was built where all the materials and construction techniques were showcased. The project is expected to be finished in the Year 2020.

There are some similarities of design principles for these example projects. It seems that main importance is given to buildings' function and functionality, closely followed by building component design and material analysis. By making the best possible design with great indoor environment and experiences building will not become outdated for longer time period, therefore investment in this building will last longer. In all these example projects architects pay great attention to material selection, choosing only materials that could be reused, recycled or biodegraded. In order to successfully reuse, recycle and biodegrade materials it is important to design building components in a way that they could support this process in the future. Good component design will allow to disassemble buildings and reuse the components, with the possibility of breaking down the components by material to recycle them or biodegrade them.

Green solution house and BSH building improves indoor experience by creating well daylit public spaces. In the circular house project architects and investors have constructed showcase building to introduce potential residents with project and invite suggestions of design improvements. With these design methods architects are placing user experience above all other design aspects. All these projects are taking advantage of modular design, suggesting that same components could be reused in the future for different projects. Materials used in projects are applied in such a way that it is easy to separate component on material basis. For example, insulation is placed between wooden studs, making it easy to remove and reuse, or recycle. If it was glued, then it would be impossible to remove all of the material and reuse it in a different project.

Design principles from these projects can be used as guidelines for future work. I will implement these findings for re-modelling the apartment building in Finland for Active House certification.

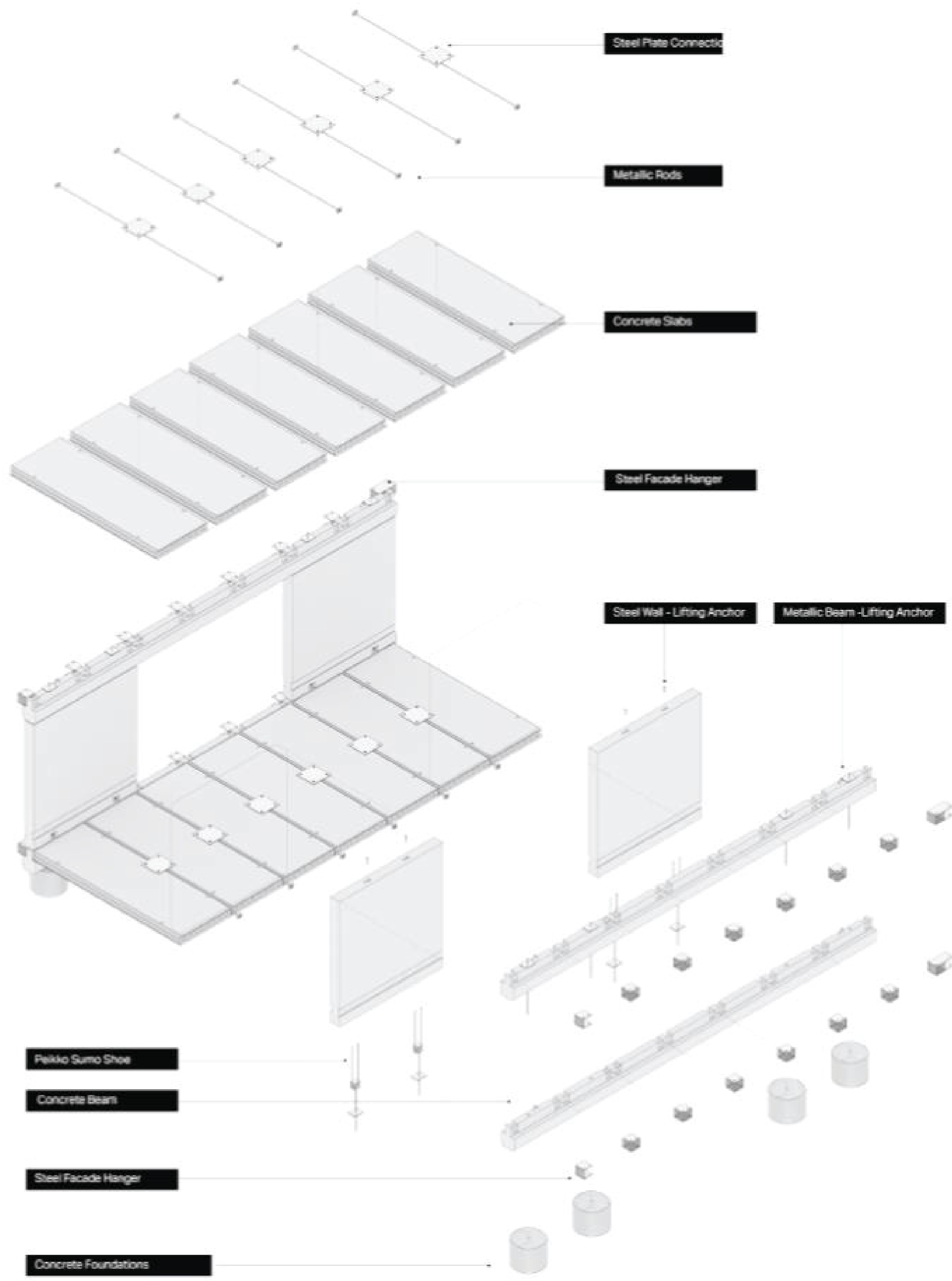


Figure 11Circle House exploded axonometry by GXN architects, https://gxn.3xn.com/project/circle-house-demonstrator

2 DESIGNING ACCORDING TO ACTIVE HOUSE PRINCIPLES

This study explores what changes could be implemented in Finnish architecture to follow Active House principles. A recently finished multistorey apartment project in the Helsinki region, Taidemaalarinkatu 4 designed by architectural firm ARK-HOUSE ARKKITEHDIT OY, is set as a base point for this case-study. Maintaining the program of the building, size of the apartments, and the number of rooms, a new project will be designed, modifying the shape and materials, to meet the Active House Principles. Various simulations will be conducted to re-shape the building following the Active House Principles. At first, the Base project will be completely recreated in BIM software. The necessary information will be collected from the Building Information Model to run the simulations and analysis in software recommended by Active House. With all the collected information imported in the Active House Software, the Active House Radar Chart indicates, which areas need improvements in order for the project to qualify as an Active House. This study provides an insight of the differences between a typical Finnish design of an apartment building and an Active House design for a similar project in the same location.

2.1 Base Project

Currently there is a lot of new development in Helsinki and most of the new buildings have similar special qualities and construction. Most of the new buildings in Finland could be considered to be built following high standards, providing good indoor climate. Considering the high building quality, I was compelled to investigate how does it compare with Active House Label criteria.

The building in Taidemaalarinkatu 4 in Helsinki is designed by architectural firm ARK-HOUSE ARKKITEHDIT OY. The building could be considered as a good representation of a typical residential housing project in Finland. The main indications of a typical project are the building's special design, materials used in construction, component design, building`s equipment and energy use.

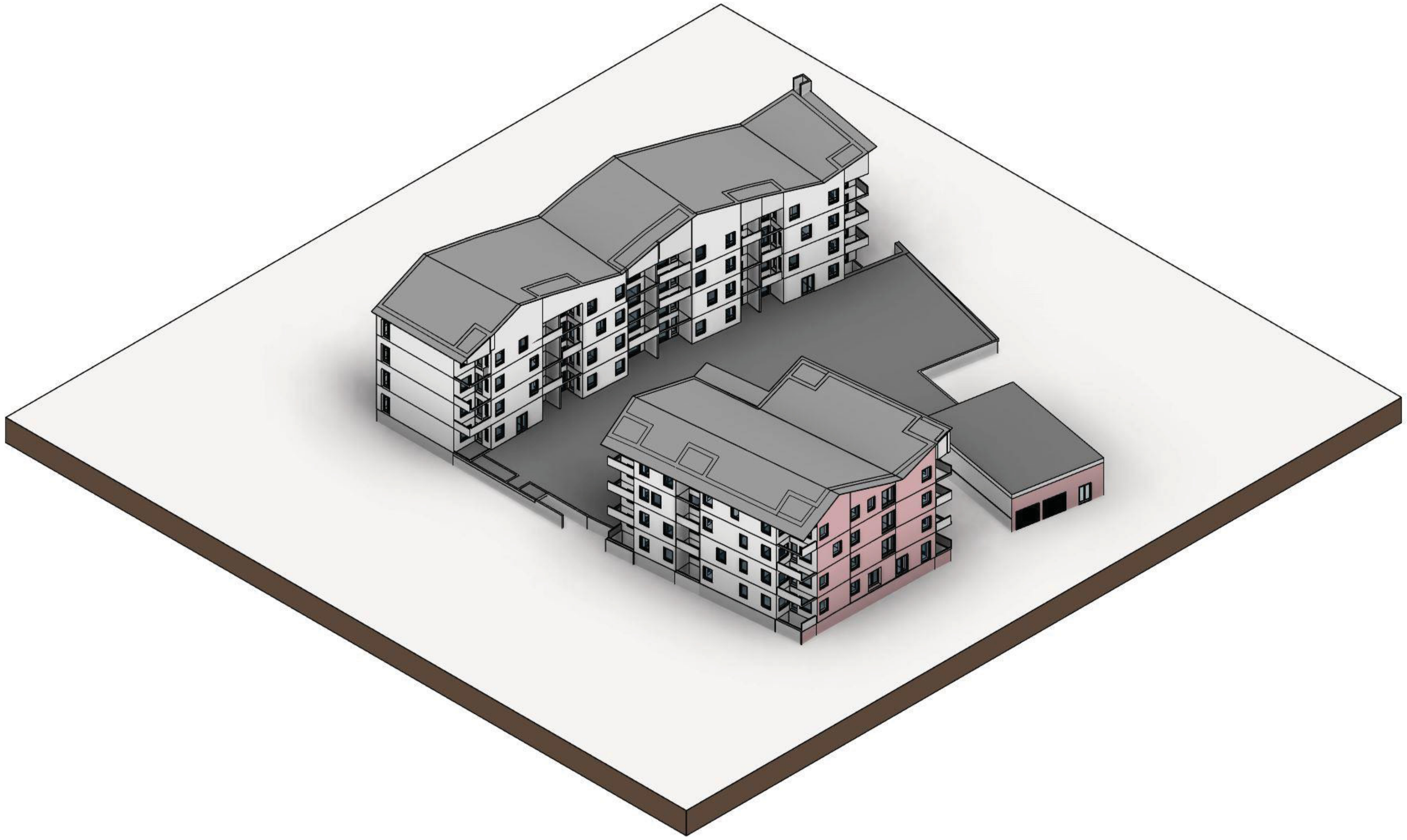


Figure 12 BIM model of the Base Project (Building in Taidemaalarinkatu 4 in Helsinki)

The estate consists of three separate blocks, each block has a separate entrance, stairs, elevators, hallways, and technical rooms. By splitting the building into 3 portions the architect has succeeded to maximize the proportion of space that is profitable. When analyzing the layout of the apartments, it is visible that this building has special design elements typical for a Finnish residential building. All apartments have a relatively low ceiling height (2.60 m) with apartment depth that exceeds 7 meters from the windows. Most of the apartments have balconies in front of the windows, which restrict the daylight entering into the rooms.

The materials used in construction also indicate methods that are typically used in Finnish residential buildings. Extensive use of concrete in load-bearing constructions, prefabricated concrete wall elements with insulation, mineral and oil-based thermal insulation materials, and waterproofing materials all indicate well- known construction methods that have been extensively tested and employed for many years.

The architects of the building have confirmed that the equipment embedded in the building does not stand out from the ordinary building practices. The building has central mechanical ventilation system. The building is connected to the district heating system and has 57 solar panels in a 13kW system that would provide around 10 600 kWh/year. This energy most likely would offset energy consumption from public zones and elevators.

The energy-efficiency of the buildings massing is hindered, as it consists of two separate blocks, that are shading each other. The structure of the building has concrete balconies that create thermal bridges and triple glass windows that contribute to energy efficiency. However, the balconies do not have blinds which could provide additional energy savings. There are no indications of a rainwater collection system or greywater recycling.

Figure 13 2nd floor plan of Building in Taidemaalarinkatu 4 in Helsinki designed by architects firm ARK-HOUSE ARKKITEHDIT OY, source Hannu Huttunen

Figure 14 View on the Base project (Building in Taidemaalarinkatu 4 in Helsinki)

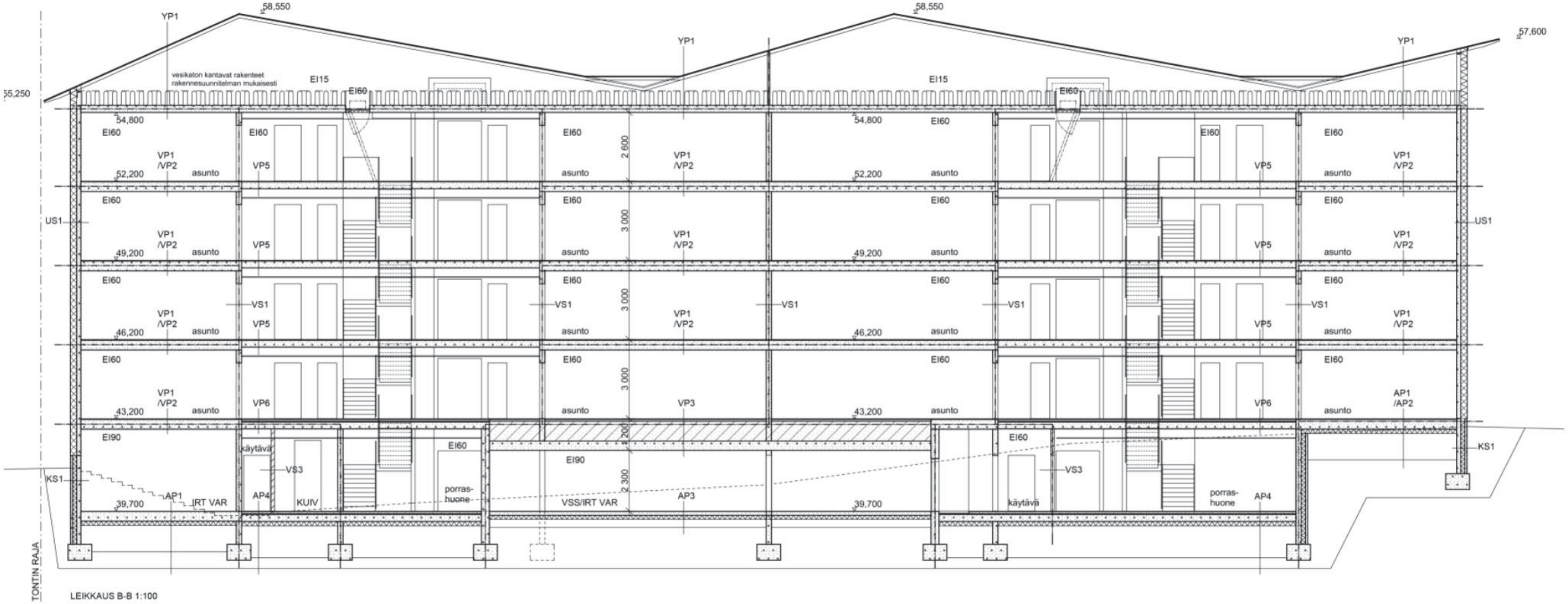


Figure 15 Section of Building in Taidemaalarinkatu 4 in Helsinki designed by architects firm ARK-HOUSE ARKKITEHDIT OY, source Hannu Huttunen

2.2 Data from the Base Project

By redrawing the Base Project in BIM software, it was possible to gain access to all the needed information to analyze this typical Finnish multistorey apartment building based on the Active House Principles. Redrawing was needed for identifying the program of the Base Project and using it as a brief for the Active House apartment building.

The information in the Active House Radar chart shows that the main areas of focus for improving the existing design are indoor daylight access, energy supply, freshwater consumption, and construction materials. If the Base Project design had larger windows, was designed for disassembly, and systems that help reduce freshwater consumption by using rainwater or reusing gray water, then this project could meet all Active house criteria and would qualify for Active House label. Analysis results from Base Project suggest that most typical apartment buildings in Finland do not meet all Active house criteria but with some design changes they could get certified.

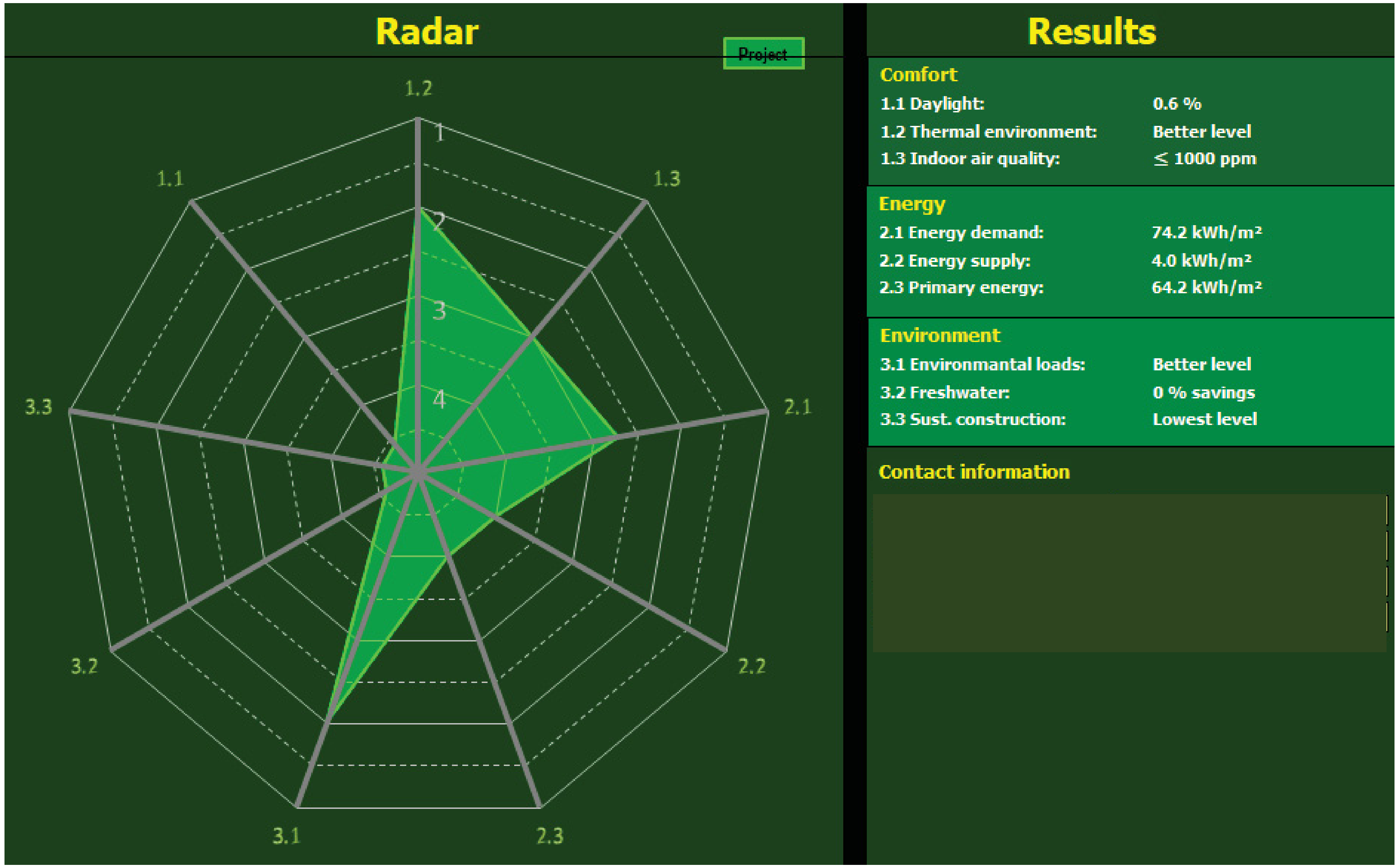


Figure 16 Radar chart From Active House software for Base Project

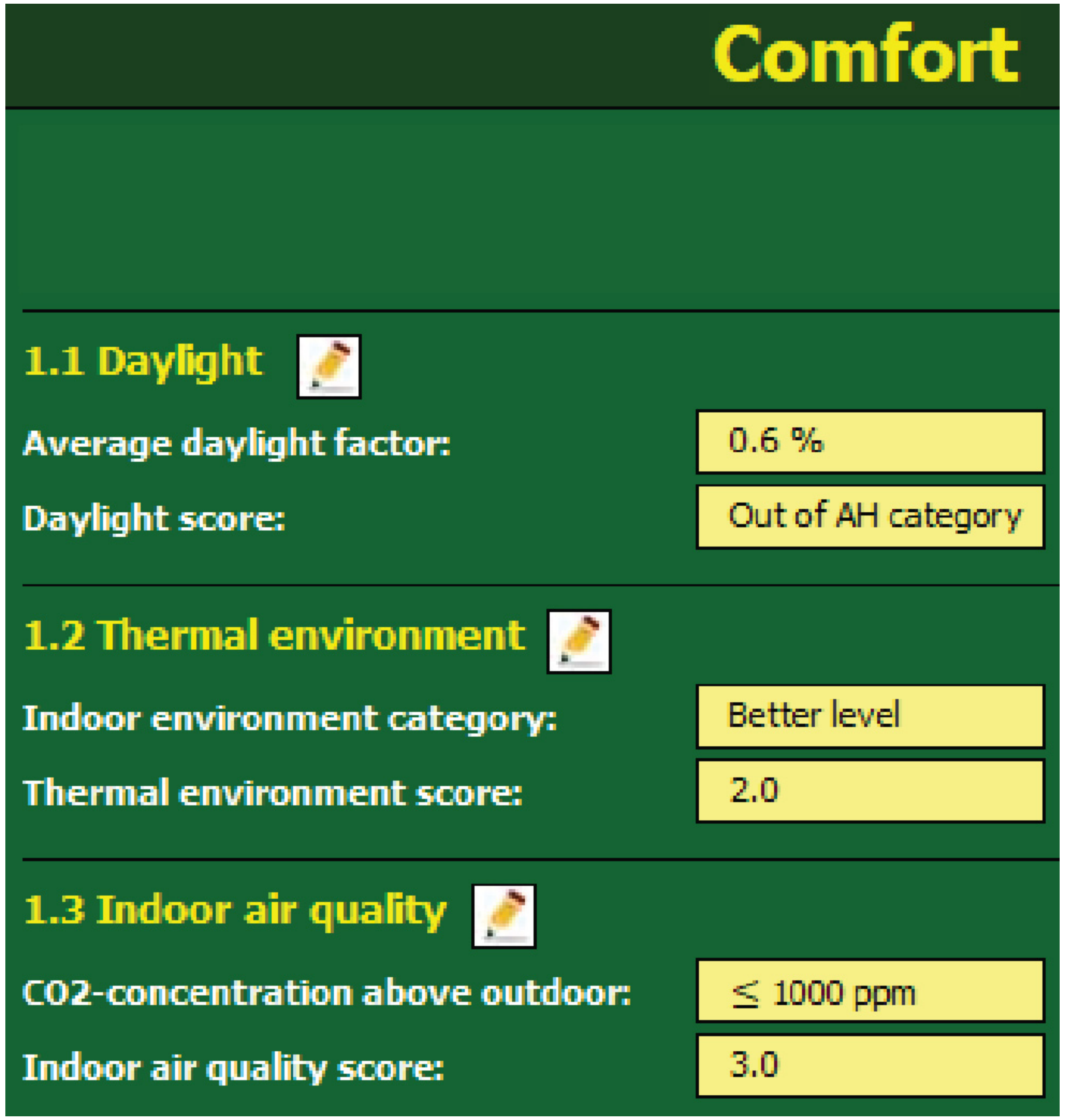


Figure 17 Comfort analysis results from the Active house tool

The Active House comfort section focuses on occupant's wellbeing. Comfort section consists of three criteria: daylight- assessing the amount of day available indoors, thermal environment – assessing the indoor temperature, and indoor air quality – projecting CO2 concentration indoors.

Daylight Factor (DF) is percent value of available indoor daylight from amount of daylight available outdoors. Overcast sky is used in calculation of daylight factor. In the Base project, the indoor daylight level does not meet the minimum Active House daylight criteria of at least 1 % of the DF. This value was calculated with Active House suggested software (Velux daylight Visualizer 2) and verified with other software (Ladybug, Rhino plugin for grasshopper). The main reason for the low DF result is the depth of rooms and the shading from the balconies.

The Thermal environment values of the Base project are good according to Active House criteria. Typical apartment building would have a good envelope, minimizing unwanted cold drafts in the winter, and district heating regulating temperature in wintertime. Balconies in front of large openings are providing shade and reducing solar gain during summer months.

The Indoor air quality is directly correlated to the CO2 levels in the air. There are many pollutants in the indoor environment that affect air quality, but their concentration levels in the air usually are a lot lower than CO2 levels produced from human breathing. Therefore, the CO2 level in the air is taken as the variable for measuring the indoor air quality.

To calculate CO2 level in the air we need to know designed ventilation system flowrate, the volume of the ventilated room, and number of occupants. For this calculation I assumed that space is well ventilated and has 2 air changes per 1 h. For calculations I chose an apartment with 40 m2 size and possible 4 occupants that have low activity level. Calculation was done using an online tool.[16]

[16] https://www.engineeringtoolbox.com/pollution-concentration-rooms-d_692.html

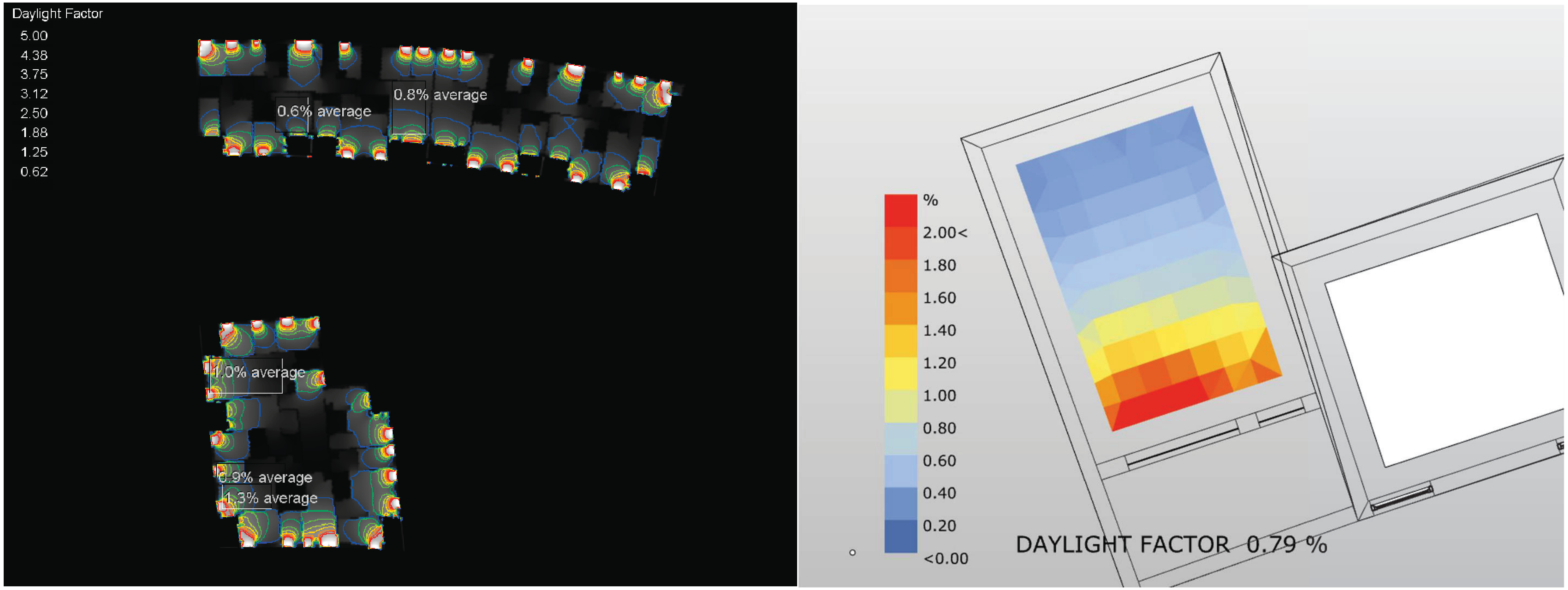


Figure 18 on the left side Daylight Factor Simulation for the Base projects 2nd floor, Software Velux daylight vizualizer 2 and on the right side test of Rooms daylight factor values, software Rhino, Grashoper, Ladybug plugin

Daylight calculation was done with Velux Visualizer 2 and provided the same results as the calculations in Rhino with Ladybug plugin for Grasshopper. All the rooms have similar lighting conditions and as it is stated in the Active house – the lowest score sets the overall daylight score. With that it is safe to assume that the base project does not meet the active house daylighting criteria of reaching at least 1 % level in Daylight factor (DF) calculations.

Active House - Indoor environment evaluation

Input parameters

Desciption of room	APARTMENT
Date of calculation (DD/MM/YE)	19.05.2019.
Is the space mechanically cooled?	No
What is the outdoor CO2 concentration	400

Results

Thermal environment	
Maximum operative temperature	2
Minimum operative temperature	2
Indoor air quality	
Standard fresh air supply, overall	3
Standard fresh air supply, summer	3
Standard fresh air supply, winter	3

Figure 19 Indoor environment results from the Active house software

The Carbon dioxide concentration in a room filled with persons after a time - *t* - can be calculated as

$$c = (q / (n V)) [1 - (1 / e^{n t})] + (c_0 - c_i) (1 / e^{n t}) + c_i \qquad (1)$$

where

c = carbon dioxide concentration in the room (m^3/m^3)

q = carbon dioxide supplied to the room (m^3/h)

V = volume of the room (m^3)

e = the constant 2.718.....

n = number of air shifts per hour (1/h)

t = time (hour, h)

c_i = carbon dioxide concentration in the inlet ventilation air (m^3/m^3)

c_0 = carbon dioxide concentration in the room at start, $t = 0$ (m^3/m^3)

For the Thermal environment calculation, the Active house tool was used. Input values were generated with Velux indoor climate visualizer

Calculation of CO_2 concentration in 40 m^2 apartment with 4 occupants with low activity level.

$$C = ((0.2\ m^3/h) / (2\ h^{-1}) (104\ m^3)) [1 - (1 / e^{((2\ 1/h)\ (3\ h))})] + ((0.0004\ m^3/m^3) - (0.0004\ m^3/m^3)) (1 / e^{(2\ 1/h)(3\ h)}) + (0.0004\ m^3/m^3)$$

$C=0.00136 m^3/m^3$ = <u>1370 ppm</u>

q= 0.2 m^3/h (4 persons low activity level V=104 m3 n= 2/h t= 3 C_i =400 m^3/m^3 C_0 =400 m^3/m^3

In the Active house certification to meet the criteria for 3rd Level of indoor air quality CO2 levels should be lower than 1000 ppm above the outside levels. In the Calculation results are slightly lower with added 970 ppm to 400 ppm outdoor level. The Base project meets the Active house criteria for air quality with a score of 3.

Energy

General information		
Treated floor area:	3500.0	m2
2.1 Energy demand		
Space heating:	54.2	kWh/m2
Domestic hot water:	10.0	kWh/m2
Mechanical ventilation:	5.0	kWh/m2
Cooling:	0.0	kWh/m2
Control systems:	0.0	kWh/m2
Lighting:	5.0	kWh/m2
Total:	74.2	kWh/m2
Energy demand score:	2.7	
2.2 Energy supply		
Electricity produced by renewable energy:	4.0	kWh/m2
Heat produced by renewable energy:	0.0	kWh/m2
Total:	4.0	kWh/m2
Percentage of renewable energy supply:	5.4	%
Energy supply score:	4.0	
2.3 Primary energy performance		
Total:	64.2	kWh/m2
Primary energy performance score:	4.0	

Figure 20 Energy analysis results from the Active house tool

The Active House energy section focuses on the energy flow of the building. All values are expressed in kWh / m2 of building / annually. Energy demand is calculated considering all the equipment that requires energy for operation. The Active House Label recommends using local energy calculation method for generating the input values for the Active House calculation tool.

In this case the PHPP8.5 Passive house calculation tool was used. The values generated with PHPP8.5 will be in close range with the local calculation method and is internationally recognized as an accurate calculation method.

The calculated renewable energy production from the onsite equipment is evaluated in the Active House energy supply criteria. In the façade and roof drawings of the project it is visible that there is a solar panel system for generating electricity on the roof of the building set as a Base project. To calculate the amount of electricity generated online calculation tool PVGIS-5 was used. Then value was divided by treated floor area and placed in the Active House calculation tool

Primary energy Performance is calculated automatically. Calculation considers the location of the project, energy demand and supply.

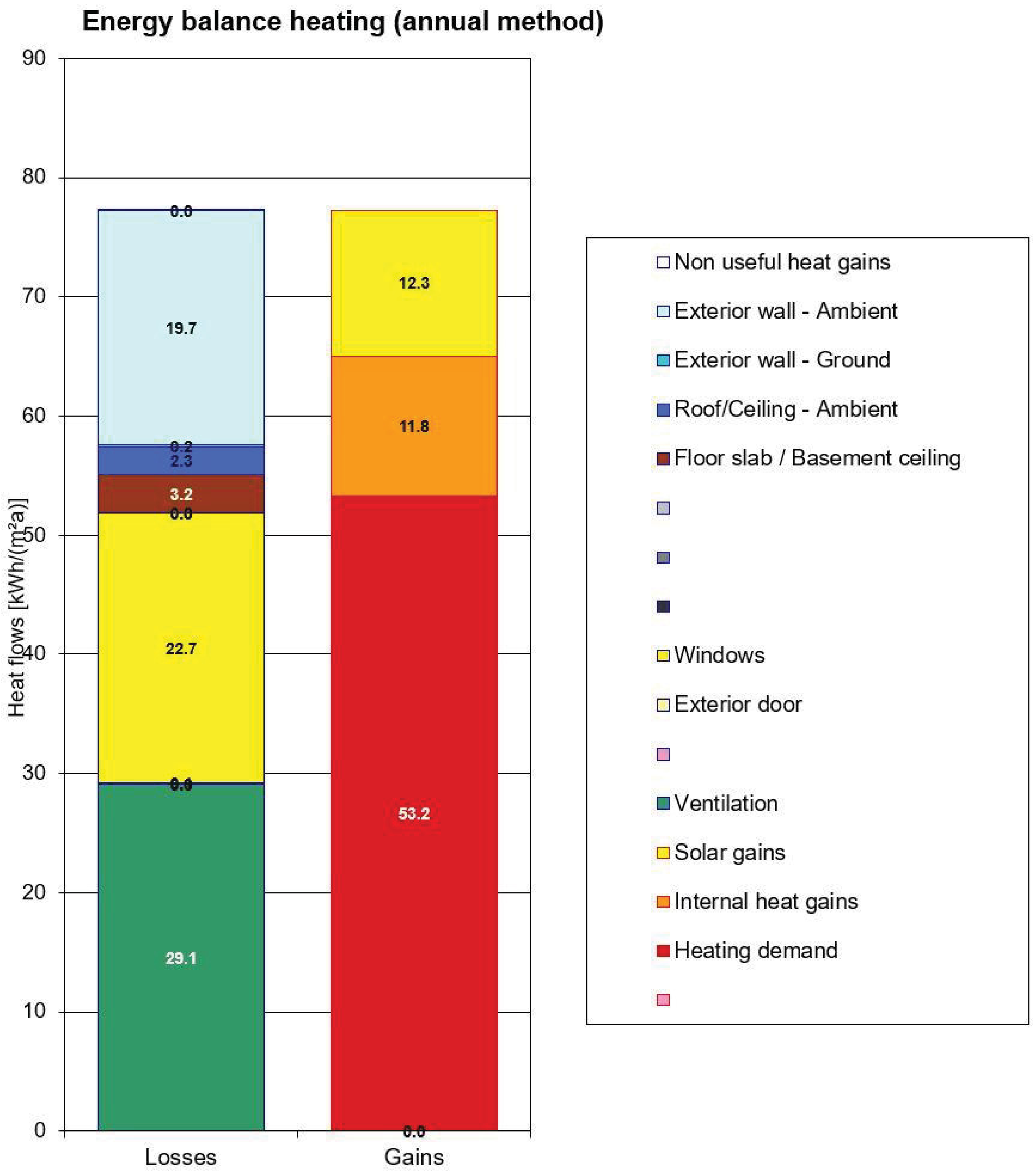


Figure 21 Energy balance graph from PHPP 8.5

This chart from the Passive house calculation tool PHPP8.5 illustrates amount of energy required to maintain energy balance. In this graph the areas that contributes to energy losses and areas that provides energy gains are depicted.

Main loss areas are

- Ventilation system
- Heat loss through the windows
- Heat loss through the exterior walls

Main Gain areas are

- Solar gain –solar energy heating the space through the windows
- Internal heat gain – heat production from people and indoor activities

Heat demand (red) illustrates the amount of energy required to maintain indoor comfort and energy balance. Energy demand can be reduced by reducing the energy losses. The primary energy loss is caused by the ventilation. Reduction of the energy loss from the ventilation could be achieved with different strategies - use of Hybrid system (mechanical system in combination with natural ventilation in summer) and decentralized mechanical system (instead of a large ventilation unit that supplies multiple apartments each apartment would have their own unit).

Heat loss from the windows is usually reduced by using better window installations and using windows with lower U-Values. The Base project windows have good U-values and installation methods. Therefore, innovative approaches will be required to further reduce heat losses from the windows.

Heat losses from external walls could be reduced with a buffer zone, like, a greenhouse that is attached to the building. In the winter sun will heat up the glazed space and reduce the outside temperature of the external walls.

PVGIS-5 estimates of solar electricity generation:

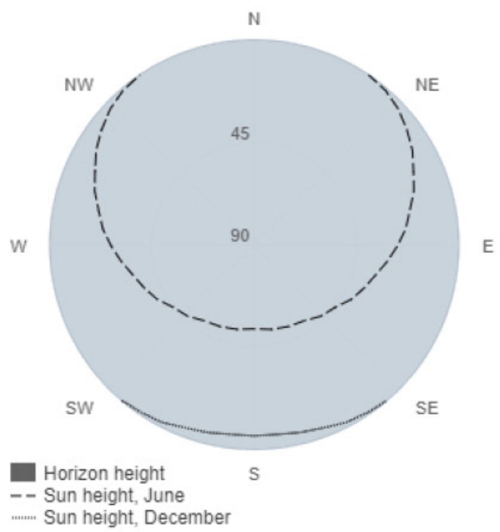
Provided inputs:

Latitude/Longitude:	60.171, 24.933
Horizon:	Calculated
Database used:	PVGIS-SARAH
PV technology:	Crystalline silicon
PV installed:	14.25 kWp
System loss:	14 %

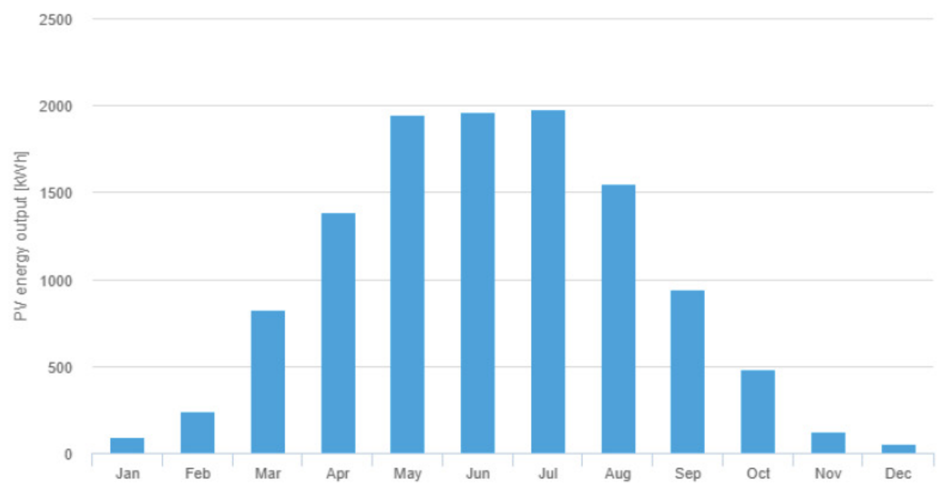
Simulation outputs

Slope angle:	14 °
Azimuth angle:	0 °
Yearly PV energy production:	11588.56 kWh
Yearly in-plane irradiation:	1034.19 kWh/m²
Year-to-year variability:	536.42 kWh
Changes in output due to:	
Angle of incidence:	-3.61 %
Spectral effects:	NaN %
Temperature and low irradiance:	-5.14 %
Total loss:	-21.36 %

Outline of horizon at chosen location:



Monthly energy output from fix-angle PV system:



Monthly in-plane irradiation for fixed-angle:

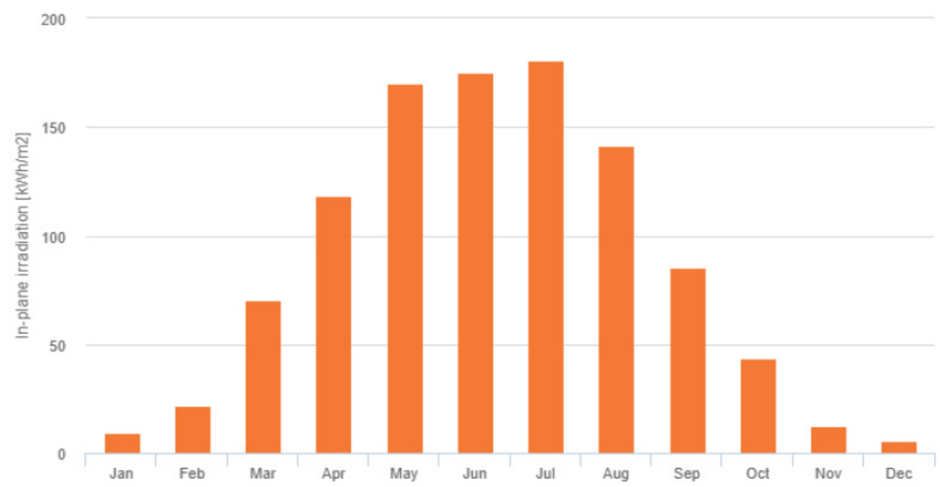


Figure 22 Solar panel systems annual energy productions calculations results. Calculations done in online tool PVGIS-5, https://re.jrc.ec.europa.eu/pvg_tools/en/#PVP

PVGIS-5 online software is a tool that helps to calculate the energy production of the Solar panels. From pictures available on Google Maps I managed to count 57 solar panels on the roof of the Base project.

The software requires location input systems power data and panel installation angle.

57 panels with 250 W peak power makes up a system with peak power of 14.25 kW

Panels are installed in a 14-degree angle.

Manual calculation of the solar panel electricity output.

Base Project Solar panels (S0)

S_0 = annual energy production from Solar panel system

Input = S_0 / buildings treated floor area

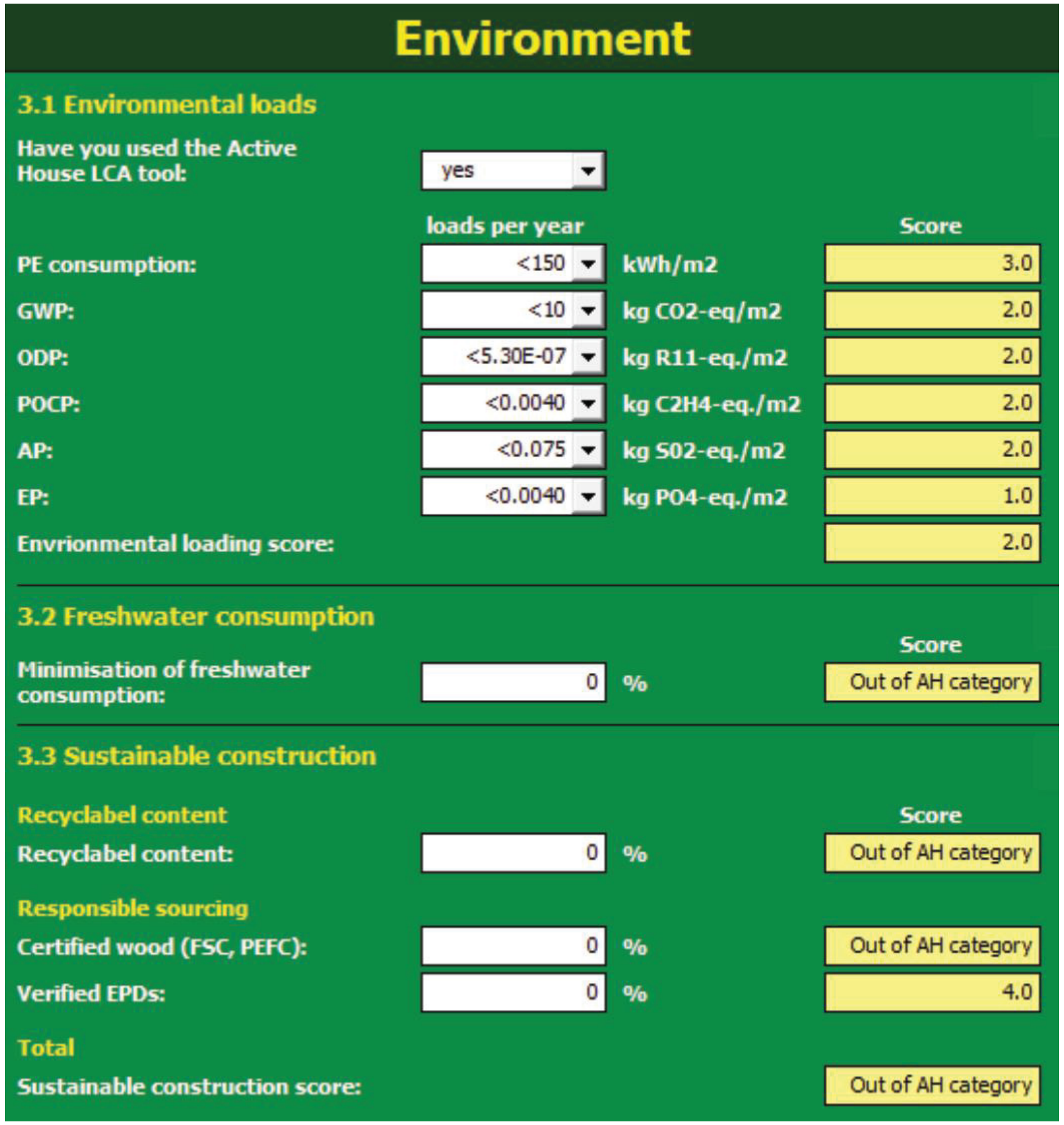
Panel energy output E= 250 W

Number of panels N= 57 pc

Systems efficiency C=90 %

S_0=E x N x C / 1000 = 250x57x0.9/1000=12.825 kWh

Input = 12.825 / 3500 = 3.66 kWh/m^2/year



Environment

3.1 Environmental loads

Have you used the Active House LCA tool:	yes		
	loads per year		Score
PE consumption:	<150	kWh/m2	3.0
GWP:	<10	kg CO2-eq/m2	2.0
ODP:	<5.30E-07	kg R11-eq./m2	2.0
POCP:	<0.0040	kg C2H4-eq./m2	2.0
AP:	<0.075	kg SO2-eq./m2	2.0
EP:	<0.0040	kg PO4-eq./m2	1.0
Envrionmental loading score:			2.0

3.2 Freshwater consumption

			Score
Minimisation of freshwater consumption:	0	%	Out of AH category

3.3 Sustainable construction

Recyclabel content			Score
Recyclabel content:	0	%	Out of AH category
Responsible sourcing			
Certified wood (FSC, PEFC):	0	%	Out of AH category
Verified EPDs:	0	%	4.0
Total			
Sustainable construction score:			Out of AH category

Figure 23 Environment analysis results fromthe Active house radar tool

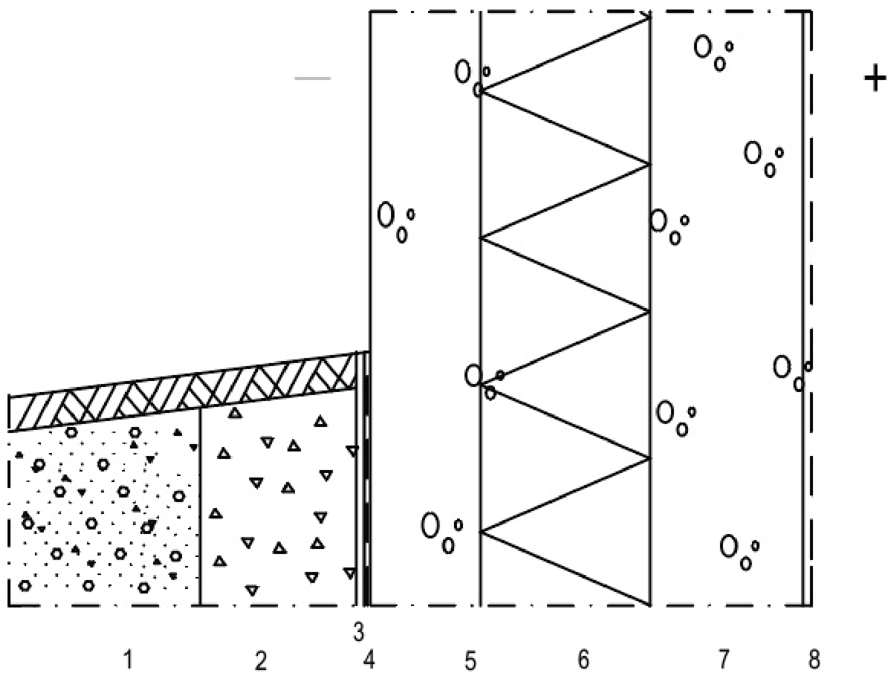
The Active House certification's environment section is addressing the construction's impact on the planet and freshwater consumption during the building operation.

The environmental load from the construction of the Base project has a surprisingly good score, considering the amount of concrete used in the construction. Concrete production requires a lot energy, therefore the score of Embodied energy in construction is lowest from all environmental load points.

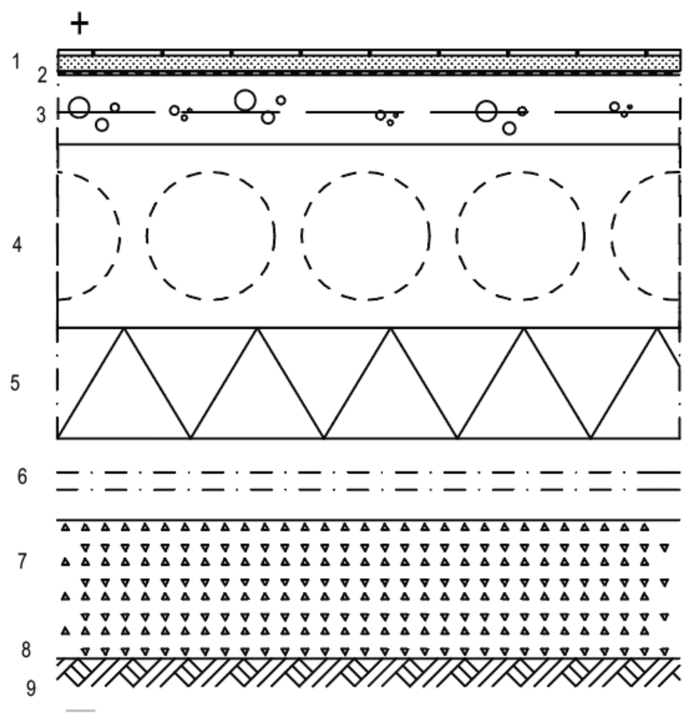
There were no visible water-saving systems in the building design, therefore, the freshwater consumption score was taken from Finland's National typical water consumption values. The Base project did not have systems like greywater recycling, rainwater collection, or even shared laundry room with industrial level washing machines that could reduce freshwater consumption and improve the freshwater consumption score above the national average. Only projects that improve on the nation average freshwater consumptions are awarded points according to Active House; thus, Base project did not receive any points under this Active House criteria.

Sustainable construction metrics are divided into 3 parts – recycling possibilities, environmental product declarations (EPD), and certified wood use. The Base project represents typical construction methods, which does not consider the possibility of future re-use of the materials and constructions. The Base project is designed from prefabricated concrete elements that usually are casted together with concrete, making it impossible to take the building apart and reuse elements in future projects. At the end of the building`s functional life, it will be demolished, and the crushed concrete will most likely be used in road beddings. Steel from the concrete elements could be re-melted and used again as a lower grade material. The building has not been designed with the notion that it will be taken down in the future. We can only guess at what parts of the building will be recyclable. Due to this ambiguity, no points of sustainable construction will be awarded to the Base project.

The construction materials used in the building are mainly concrete elements. There is only a very small amount of wood used in the roof construction and its certification is unknown. In a It is not common to show the details of the materials and products used in buildings, because typical constructions are not required to have environmental product declarations (EPD). The Active House sustainable construction value of the building could not be obtained from the general technical drawings, therefore, no value was inserted in the calculation.



	1	Tiivistetty routimaton soratäyttö
≥ 200 mm	2	Salaojituskerros, pesty salaojasepeli 6-32 mm,
	3	Suojakerros: perusmuurilevy tai vastaava
	4	Kumibitumimatto-vedeneristys maanpinnan alapuolella, yläreunaan mekaaninen kiinnitys detaljipiirustusten mukaan
130 mm	5	Teräsbetoni
200 mm	6	EPS-100, seinä
180 mm	7	Teräsbetoni, rakennepiirustusten mukaan
	8	Pintamateriaali ja -käsittely huoneselityksen mukaan



≥ 20 mm	1	Lattialaatat (huoneselityksen mukaan) ja kiinnityslaasti Tartuntasilta laattatoimittajan ohjeen mukaan
	2	Vedeneristys, sertifioitu vedeneristysjärjestelmä, (hyväksytettävä rakennuttajalla) nostetaan seinille > 100 mm valmiista pinnasta
125...160mm	3	Teräsbetonilaatta, BY 45 luokka A-4-30 keskeinen raudoitus: 5-150 B 500 K, kallistus 1:100, kaivon lähellä 1:50
370/200 mm	4	Lovettu ontelolaatta , rakennepiirustusten mukaan
170 mm	4	EPS 80S ultra , kiinnitetty ontelolaattaan
>1200 mm	5	Tuuletettu alustatila (SRMK C2)
200 mm	6	Sepeli 6...30 mm
300 mm	7	Sepeli- soratäyttö
	8	Suodatinkangas KL 2
	9	Perusmaa, kallistus salaojiin 1:50

Figure 24 Wall and floor types used in Base project, by architects firm ARK-HOUSE ARKKITEHDIT OY, source Hannu Huttunen

The wall construction used in the Base project consists of concrete sandwich elements that are impossible to disassemble and reuse or take apart (divide in bare materials) without losing material value.

The floor construction used in the Base project consists of concrete elements and oil based insulation materials as well as in wall construction. This construction after assembly is not meant to be disassembled.

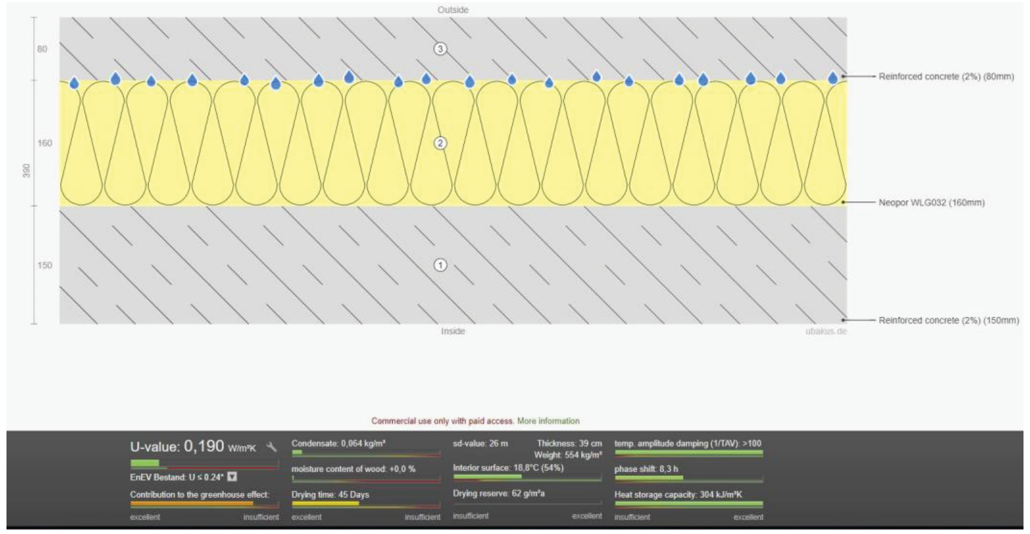


Figure 25 The Base projects wall construction analysis calculated in online tool https://www.ubakus.de/u-wert-rechner/?

Construction analysis in the online wall modeler illustrate that in the wall construction of the Base project some problems with moisture could appear over time. Analysis suggest that during the winter months the condensation between insulation and outer concrete layer will be generated. That will have an effect on the durability of the outside layer of the concrete and the performance of the insulation in long-term.

Results for AH radar tool

3.1 Environmental loads	
PE	27.7
GWP	9.09
ODP	3.03E-07
POCP	0.0026
AP	0.0281
EP	0.0037

3.3 Sustanable construction	
Recyclable content	0%
Certified wood (FSC/PEFC)	0%
Verified EPDs	0%

Figure 26 The Base projects life cycle results calculated with the Active house tool. https://www.activehouse.info/submit-your-project/create-a-radar/

Results from the Active House life cycle analysis tool. The overall results are good, despite the conventional methods of construction, which mainly entail concrete and oil and mineral insulation materials.

The data for analyzing the Base project was extracted from the information on the construction materials, shape of the building, site boundaries and the building`s program. Information on the different types of apartments in the Base project, allowed me to create models for 4 standard apartments. The new building designed according to Active House principles has the same number of floors, with all apartment types equally distributed throughout them.

The new building design will aim to get the highest Active House score possible, while maintaining the integrity of the project. In the following chapters I will discuss the design solutions that will maximize the score for all the Active House criteria.

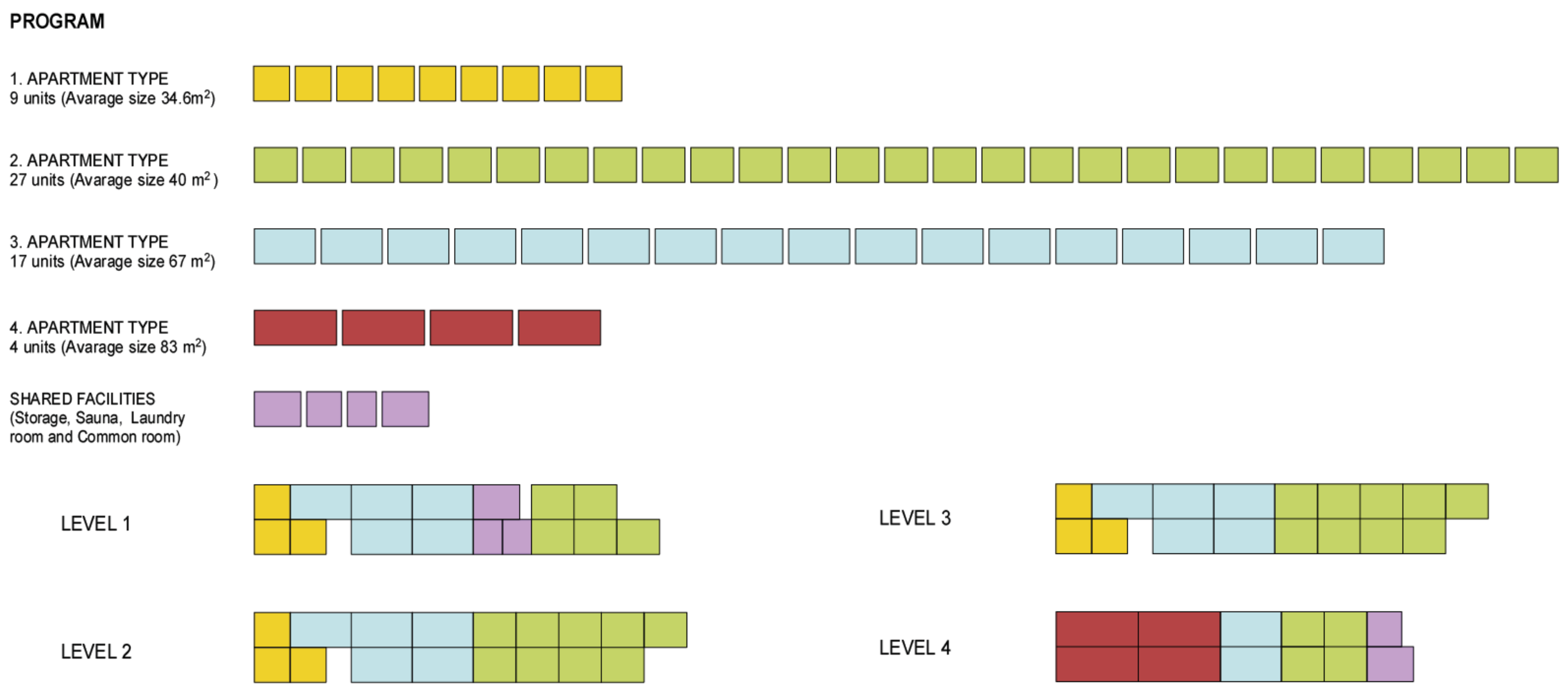


Figure 27 Buildings program in scale 1:1000

To meet the Daylight Factor (DF) of > 2.5% with windows that are 50 % of the external wall, the main design limitations were the apartments` maximum depth of 6 meters from the external façade. The illustrations below indicate that only 48.8 % of the area meets Daylight Factor value of 1,5 % or greater. Room with a size of 6m x 6m with 3 m ceiling height in this simulation meets the Daylight Factor of 2.75%. When the depth of the rooms was increased the Average Daylight factor was lower than 2.5 %. All apartments were designed with this restriction in mind.

Consideration for energy efficiency was the deciding factor for creating a single unit apartment block rather than two separate buildings that were in the Base project. A single volume minimizes the external surfaces, reducing thermal loss from the envelope. Moreover, keeping all apartments and shared facilities under one roof cultivates interactions between residents and presents an opportunity to create a closer community. Windows have lower thermal resistance than insulated walls. Energy efficiency is the main reason why Apartment has windows not more than 50 % of the external wall surface.

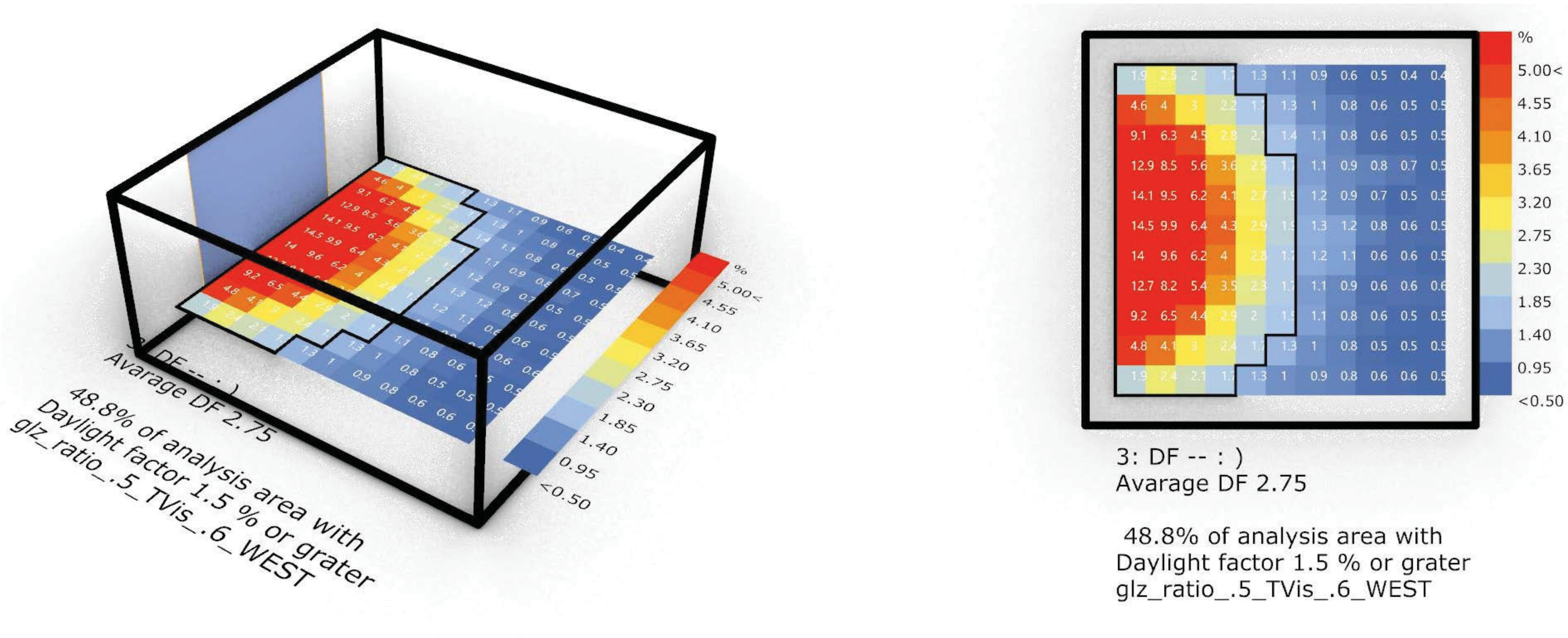


Figure 28 Daylight factor simulation done in Rhino, Grasshopper

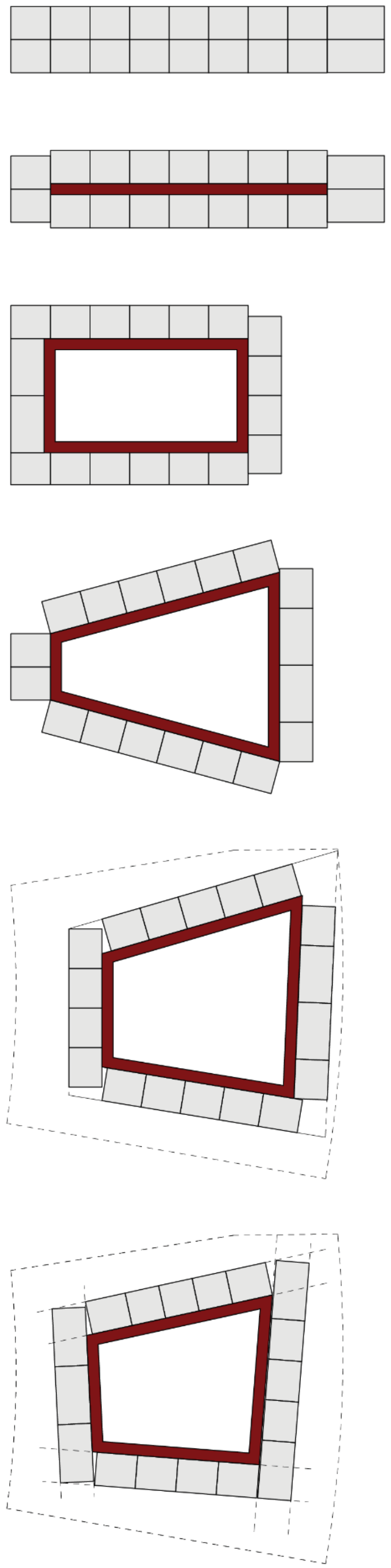


Figure 29 Buildings form finding

When the apartments were placed back to back it became apparent that a long hallway in the middle of the building would be the cheapest solution, with a practical benefit due to the amount of one room apartments with small sizes (40 m2 per unit).

An inner courtyard was introduced to reduce the length of the 68 meters long building, that would otherwise exceed the area of the given plot.

To maximize the sunlight exposure in the apartments it was decided to create a distance from the existing surrounding buildings, while leaving as little wasted space around the building as possible. With this task, the solar studies and shadow mapping were helpful tools.

When fitting the program of the building in the created form, extra attention was dedicated to the load-bearing constructions. As the external walls were matching from floor to floor only internal walls were adjusted. Eventually, grouping the apartment types allowed for internal walls to stack on top of each other. The smallest apartments were moved to the lower floors and the bigger apartments were moved to the higher floors.

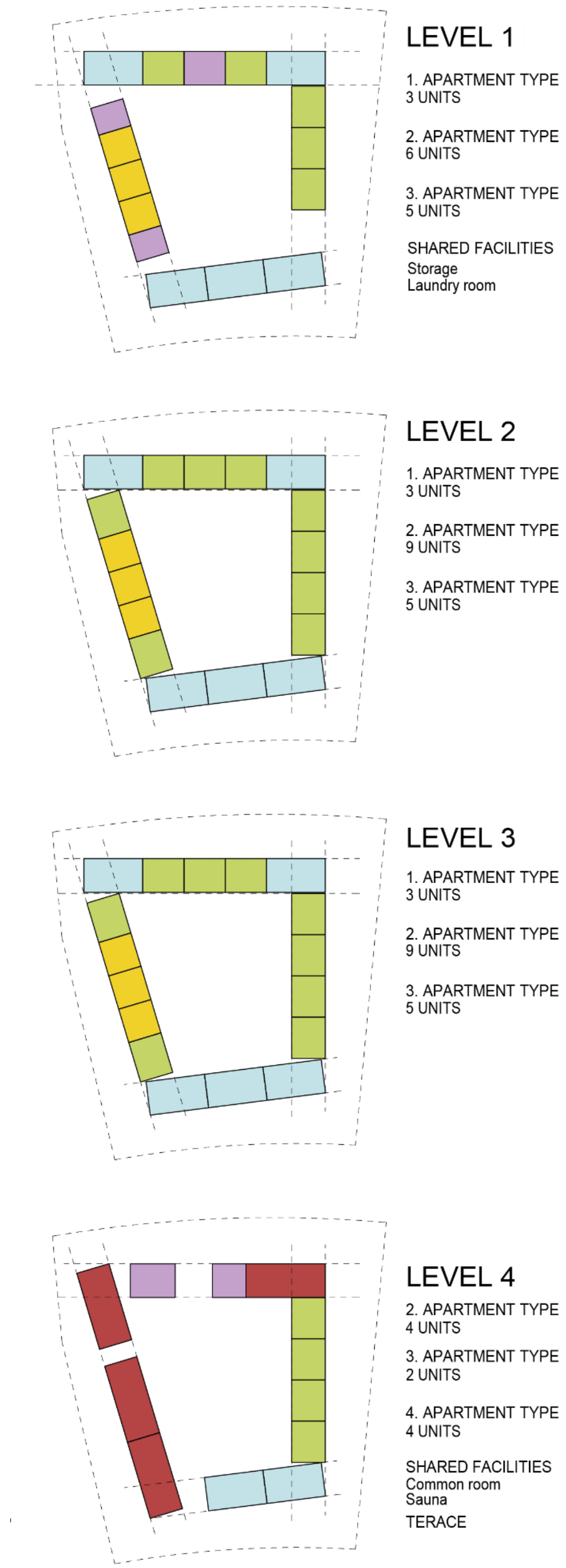


Figure 30 Buildings program on floors

2.3 Redesign

The results show that the main area of improvement according to Active House principles is Daylighting. The indoor daylight levels are affected by the shading from surroundings. To decide on the shape of the building, the solar radiation simulations on façade are performed. The building mass Radiance simulations are done with annual solar radiation and surrounding context. Parts of the façade illustrated in Red represent unwanted solar radiation during summer period, and green color represents areas with beneficial heat gain. This analysis was important to determine the building`s shape and orientation in relation to surrounding context. Picture on bottom right shows areas in red, where windows should be avoided.

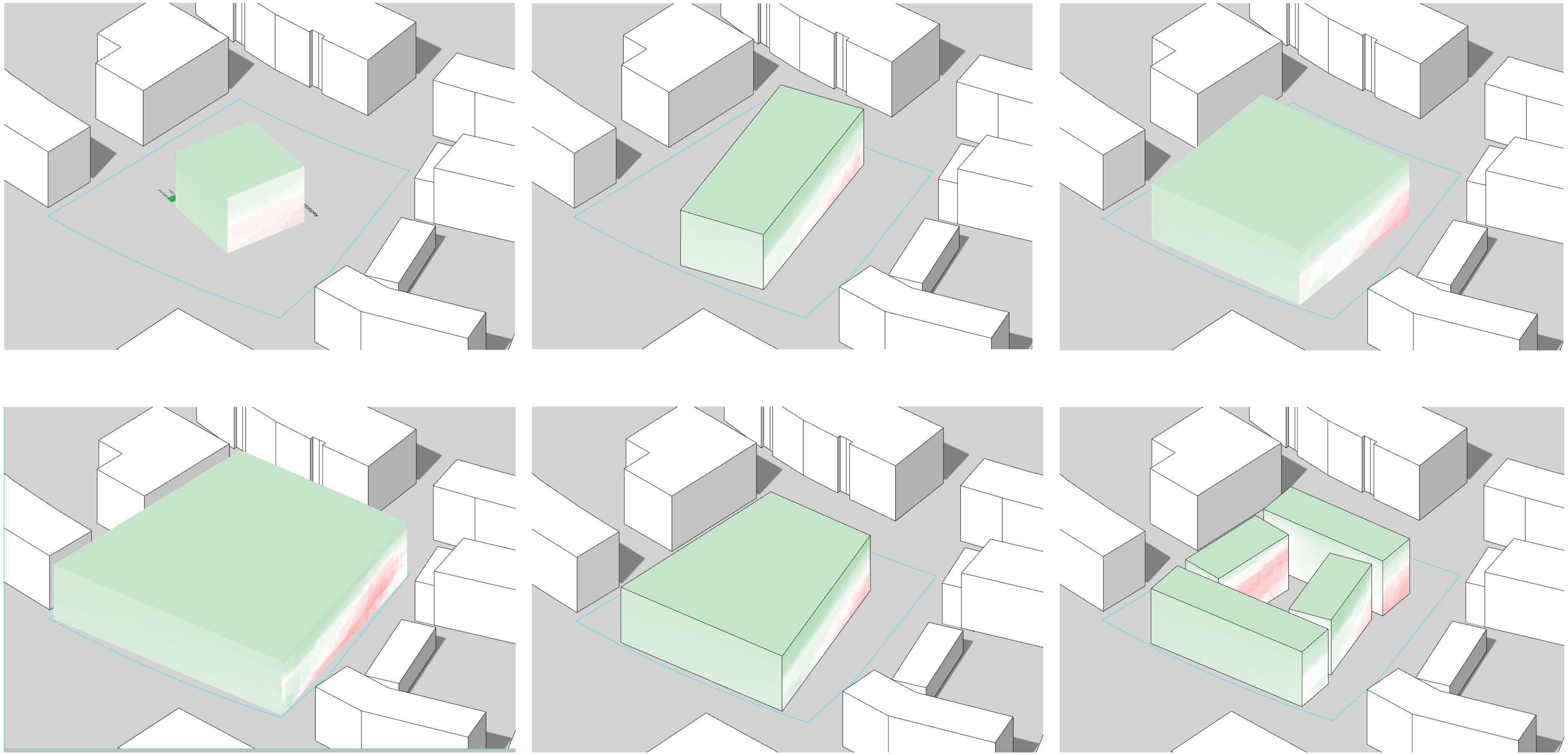


Figure 31 Form finding with positive / negative solar radiation analysis in Rhino / Grasshopper

Radiance analysis calculates solar exposure on buildings surfaces. The roof has more solar exposure than the facades, therefore the roof is better suited for PV panel installation than the walls. These analysis illustrate that the Norths façade receives very little amount of daylight energy (333 kWh/m^2) compared to the South façade (700 kW/m^2) and roof (over 1000 kW/m^2). This difference suggests that the DF calculations, that give equal sun exposure in all directions are providing misleading results. Rooms with windows in the South façade and rooms with windows in the North façade are getting the same DF values, but the amount of daylight indoors is different.

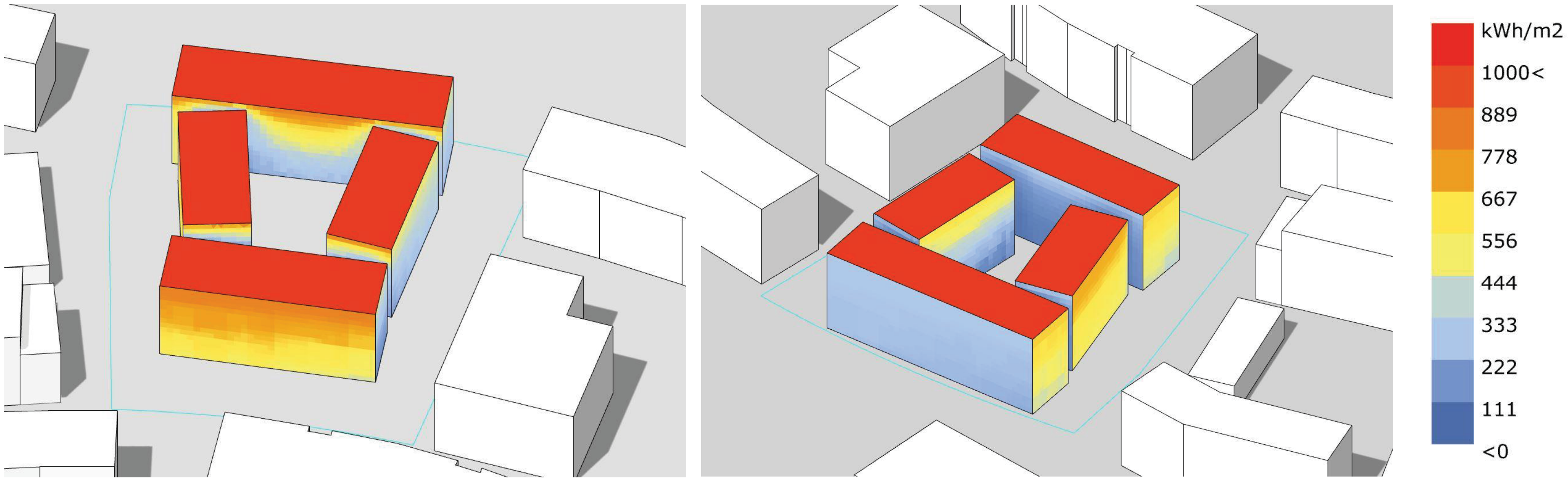
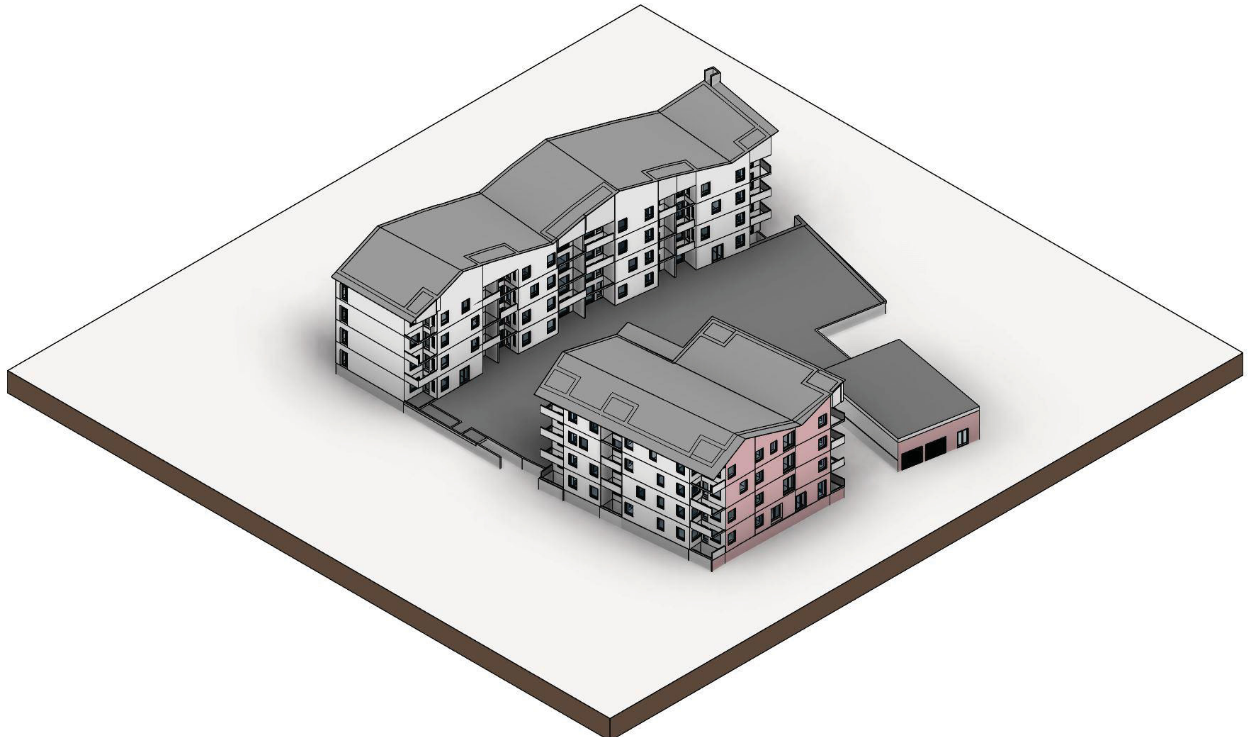
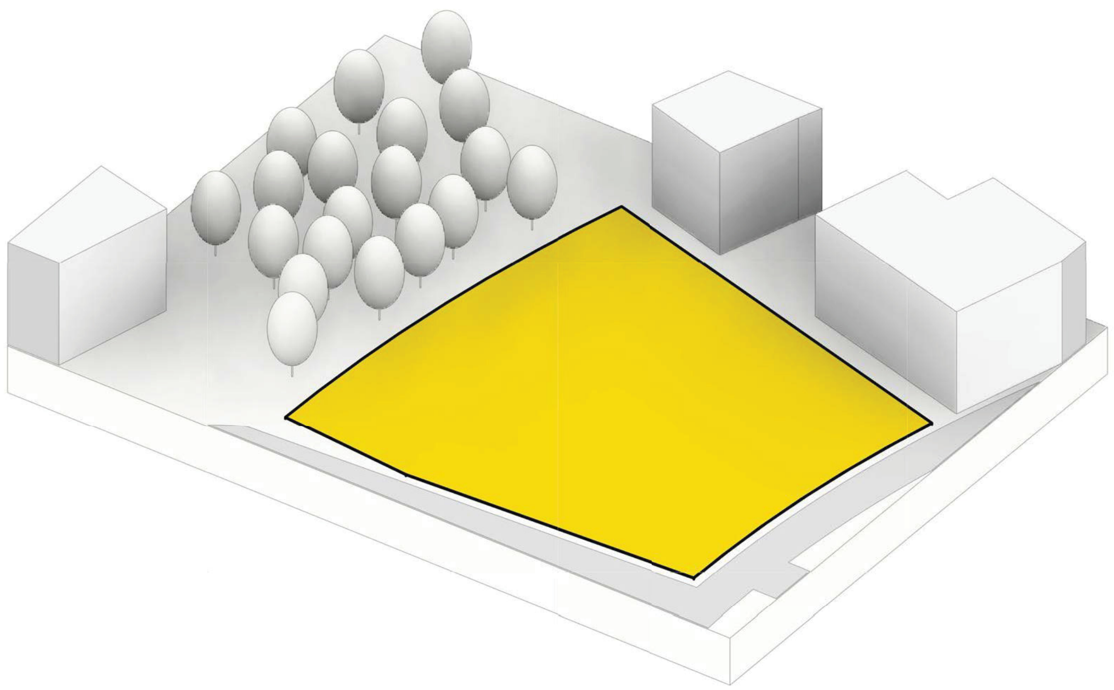


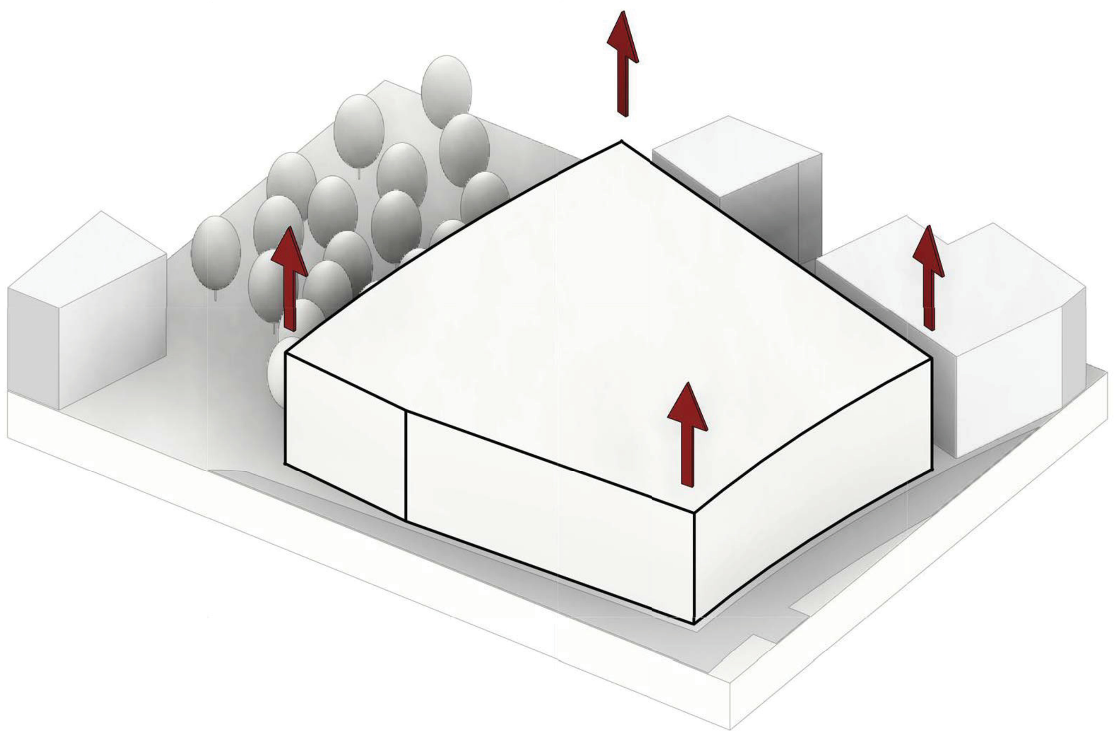
Figure 32 Radiance simulation made in Rhino



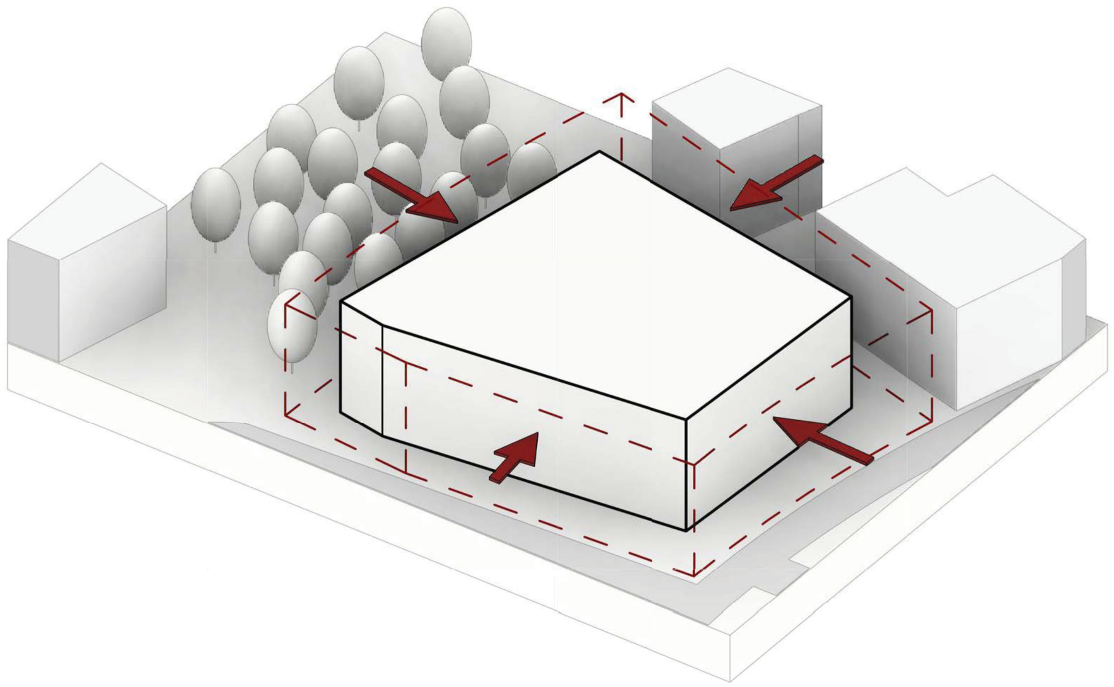
The Active House calculation tool provided guidelines for redesigning the Base project. The new project, designed on Active House principles, will share the site location, and the building`s program.



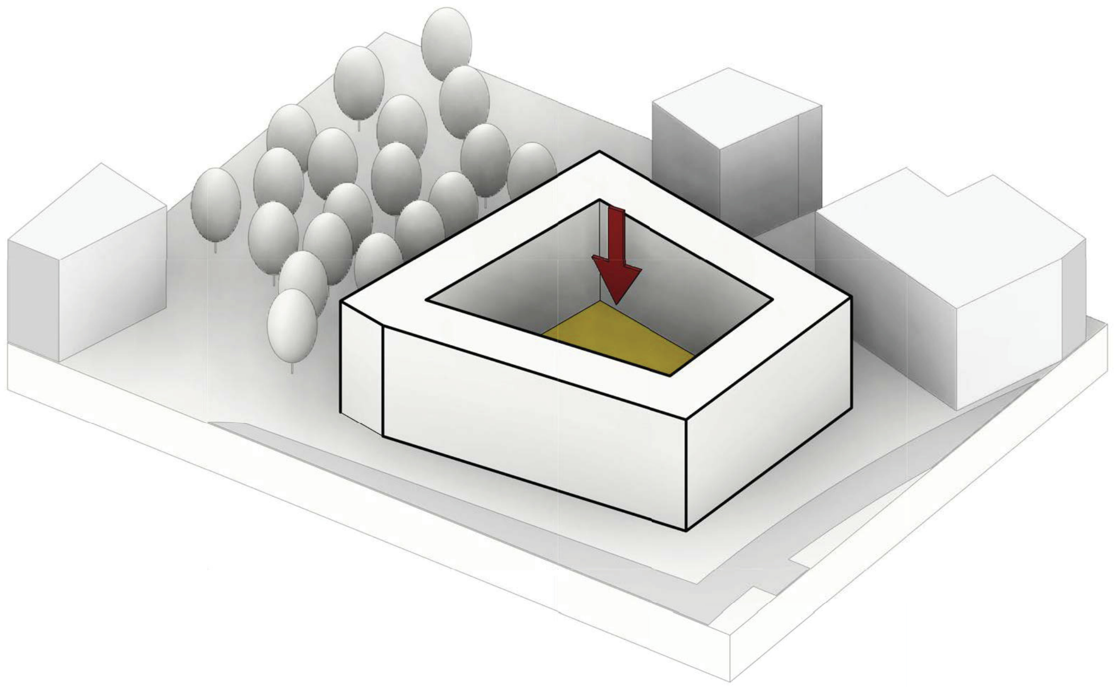
The Base project site boundaries are used for the new design.



New mass is extruded in 4 floor height

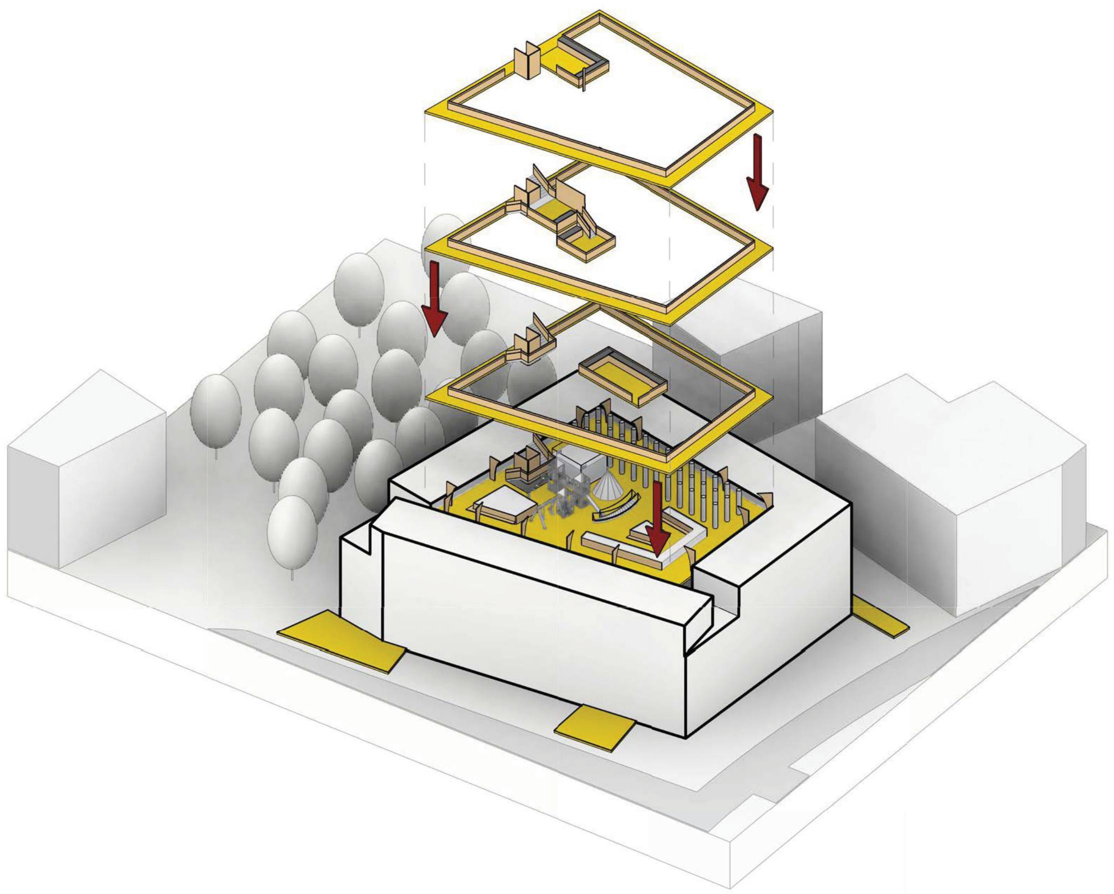


The building`s mass is set-back from the site boundaries.  A decision was made to make a set-back after the analysis of the mass as it provides better light exposure to the apartments. The set-back also gives the building`s occupants more privacy. The set-back from the property line provides more privacy and daylight to surrounding properties.



The Central Atrium functions as public space.

The Central Atrium was made to optimize the use of space for the apartments. Building`s typology mimics city blocks with perimeter typology.



New space is introduced in the Central Atrium. It serves as a semi-public function, providing the residents with space where to meet, work and play. In this space public gardens and rainwater collection tanks are located. This space is used for managing the circulations of people in the building via staircases and access balconies.

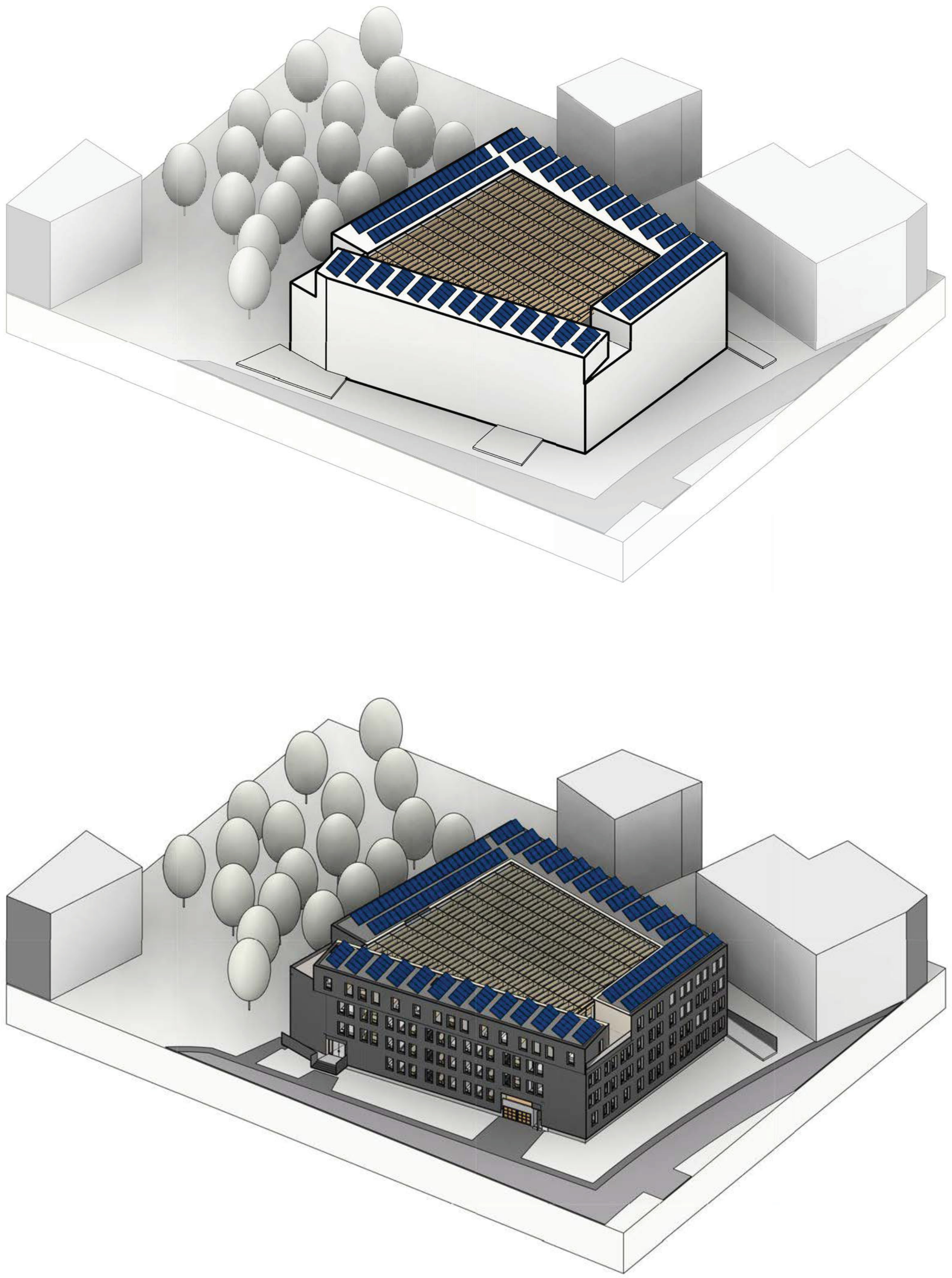


Figure 33 Buildings concept diagrams made in Revit

Central Atrium is covered with glass roof that has integrated solar cells. This glazing provides more controlled climate in Central Atrium and shading with help of solar cells. PV panels are located on rest of the roof as well, maximizing local energy production.

The location and sizing of all the façade windows were data driven. The building's façade finish would be made from burned wood. This façade stands out and lasts long without the need for repairs. Building has 3 entrances leading to the Central Atrium that gives access to all apartments.

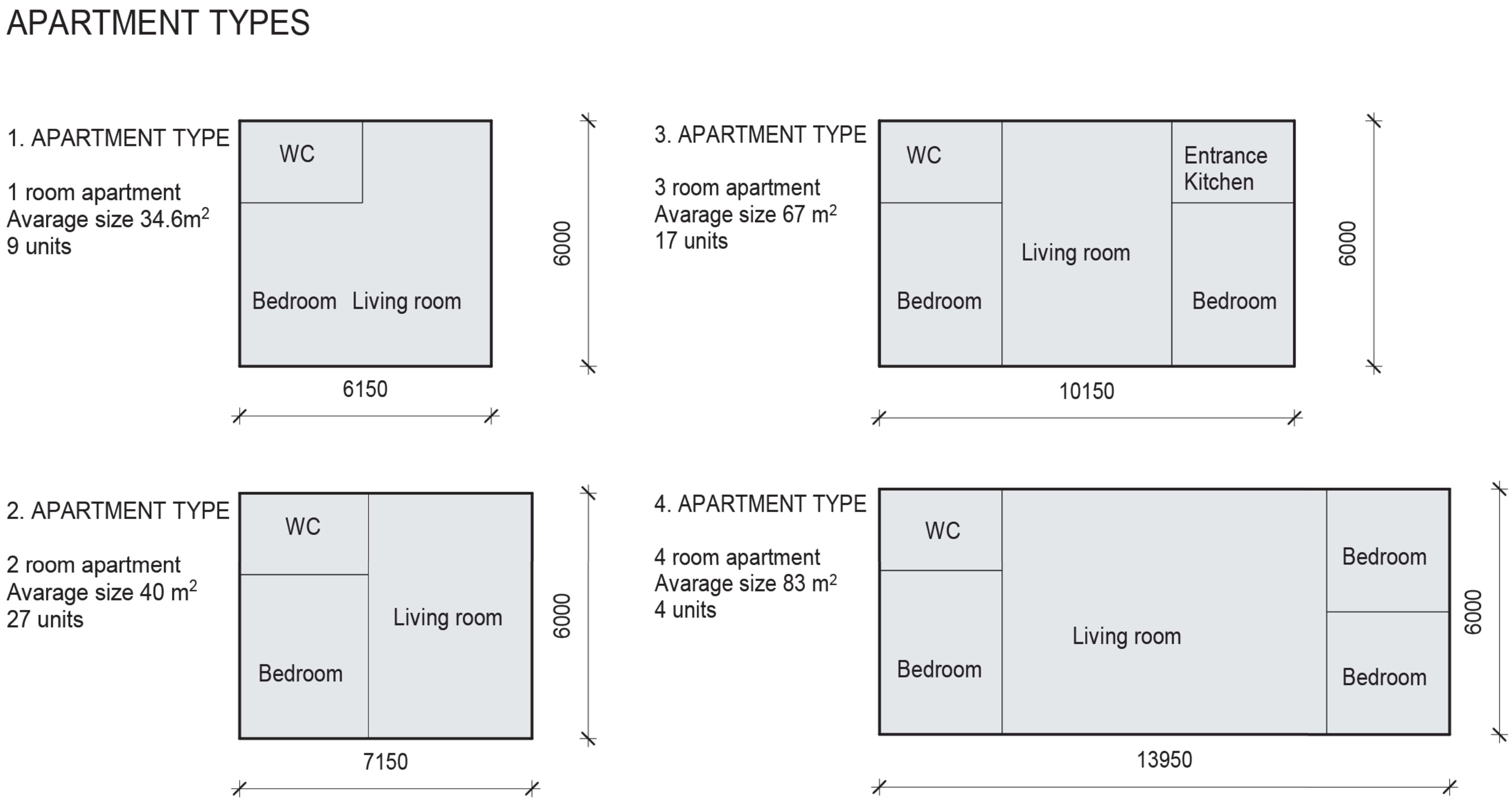


Figure 34 Active House apartment layout

2.4 Reforming apartments and building.

As indicated in the previous chapter according to Active House criteria there are many areas of improvement in the existing design. Water consumption, daylight levels and construction could be relatively easily improved to meet the Active House criteria.

Increasing the Window size and removing the balconies could provide enough daylight to meet the minimum Active House daylight criteria. But in order to make a substantial improvement in every Active House criterion, the building should be designed with the Active House criteria in mind from the very beginning. By redesigning the building on the same plot with the existing buildings program it will be possible to illustrate the differences and indicate the elements that need changing to achieve high results in Active House Label and therefore better building practices. Apartment room sizes are designed with connection of Daylight simulation that will be explained in more detail in next chapter.

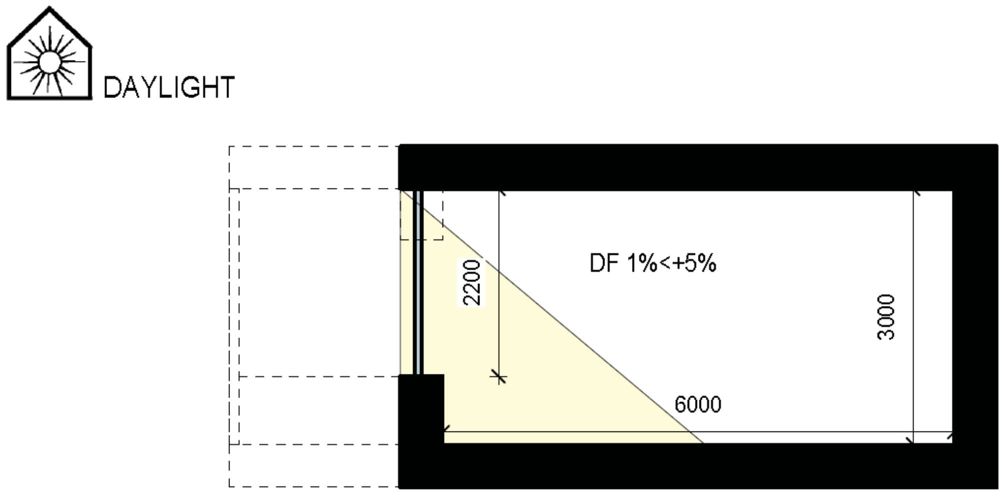


Figure 35 Daylight strategy

2.5 Daylight

Daylight is a vital factor impacting our psychological and physical health. Exposure to high levels of daylight during daytime and darkness at night influences our wellbeing. As people in developed countries spend 90 % of their time indoors it is important to ensure a good level of daylighting indoors and a visual contact to the outside.

In most cases façade windows will be preferred over skylight or light wells, as they provide daylight in the rooms and a visual contact to the outside environment and information about the weather conditions.

In the Active House Certification System, the daylight levels are measured using the Daylight Factor. Daylight Factor is the illuminance percentage of the external diffuse illuminance (Eex) projected on the indoor horizontal surface (Ein). The Daylight Factor is calculated in all main living areas. The measurement area is established in 85 cm height from floor level and 50 cm distance from walls. In this area, the Average Daylight Factor is measured.

$DF = E_{in}/E_{ex} \times 100\ \%$

Following the Active House guidelines, lighting with a Daylight Factor of 5 % (AH daylight level 1) or above will ensure that a room has a good level of light during the daytime, sufficient lighting level for reading and working. A Daylight Factor of 2 % (AH daylight level 3) will provide a modest level of daylight where electric lighting for performing detailed work would be needed. It is recommended to use skylights alongside façade windows to achieve uniform lighting. In a multistorey building, the use of skylights is not an option, therefore the aim is to ensure a sufficient lighting level. To achieve the Daylight Factor of 2 % several strategies need to be applied: reducing the depth of the rooms and increasing the ceiling height, avoiding external sun blocking elements and using the strategical placement of windows on the façade.

All new apartments were designed with the depth of 6 meters, ceiling height of 3 meters, and large windows that go up to the ceiling and have an 80 cm high sill, for maximizing the amount of light deeper into the rooms. To provide a more equal daylighting level, windows in rooms are positioned within equal distances. Windows with a high level of visual light transiency and indoor materials play an important role. Indoor materials and furniture should be as light as possible. To maximize the amount of light none of the apartments have balconies or any other obstruction in front of windows. Private balconies are replaced with access to public spaces in the courtyard. With the help of external blinds, it is possible to achieve complete darkness during nighttime.

Average Daylight Factor for Active House is calculated

- On a horizontal work plane 85 cm above the floor level and 50 cm from the walls
- Daylight Factor is calculated for each room individually
- Calculation should take the surrounding environment into the account
- Calculation includes living and activity zones
- Room with the lowest score sets the overall score of the building

The average Daylight Factor is calculated with the CIE overcast standard sky. CIE overcast sky has equal sun exposure in all directions (figure 23 overcast sky). There is no effect on the window orientation, because of the Daylight Factor sky settings. A Room with North facing windows will get the same values as a room with south-facing windows. The Daylight Factor represents the amount of the daylight available indoors from outdoor daylight. It is recommended to design rooms with uniform daylighting, but it is not required. Therefore, in designs with large façade windows, there is a risk of glare and summer overheating. Another limitation of the average Daylight Factor calculation for an Active House is the lack of occupancy schedules, and building types – a typical apartment building will be occupied by its residents mostly in the mornings and evenings when the sun is relatively low and facing the East or West façade.

DF = (Ei /Eo) x 100 %

DF – daylight factor

Ei – illuminance indoors

Eo – illuminance outdoors

Considering all the advantages and disadvantages of the average Daylight Factor calculation, it becomes clear that it will be hard to achieve a Daylight Factor of 2 % in all rooms, as they differ in size. Generating 1600 versions of 1 room in Rhino/ Grasshopper and calculating the Daylight Factor for each of them gave the data of all the possible situations. By using the Design Explorer, I managed to visualize the data and define room parameters that would achieve acceptable Daylight Factor results, in this case around 2,5%.

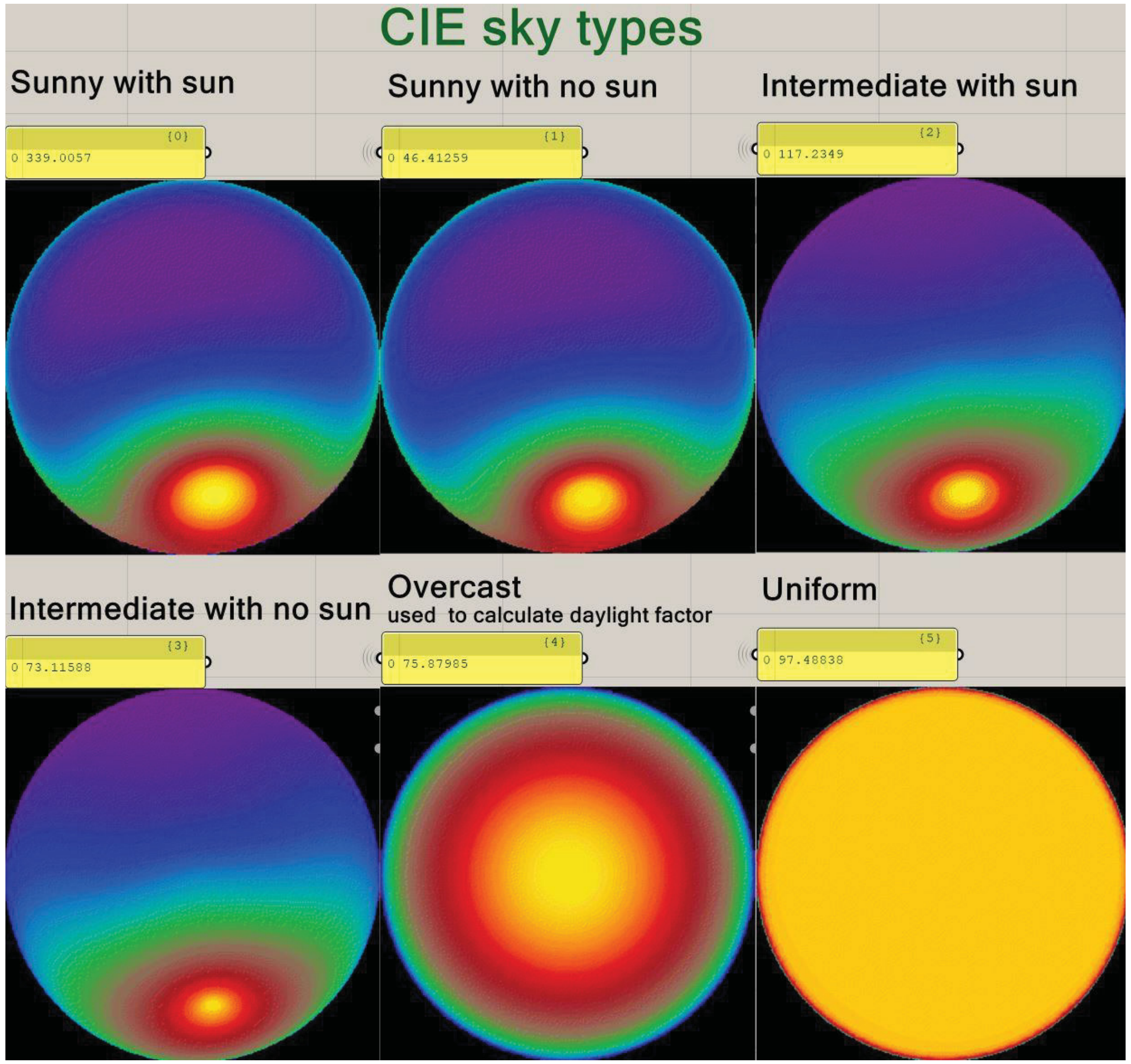


Figure 36 Sky types, illustration Made in Rhino, Grasshopper with Ladybug plugin

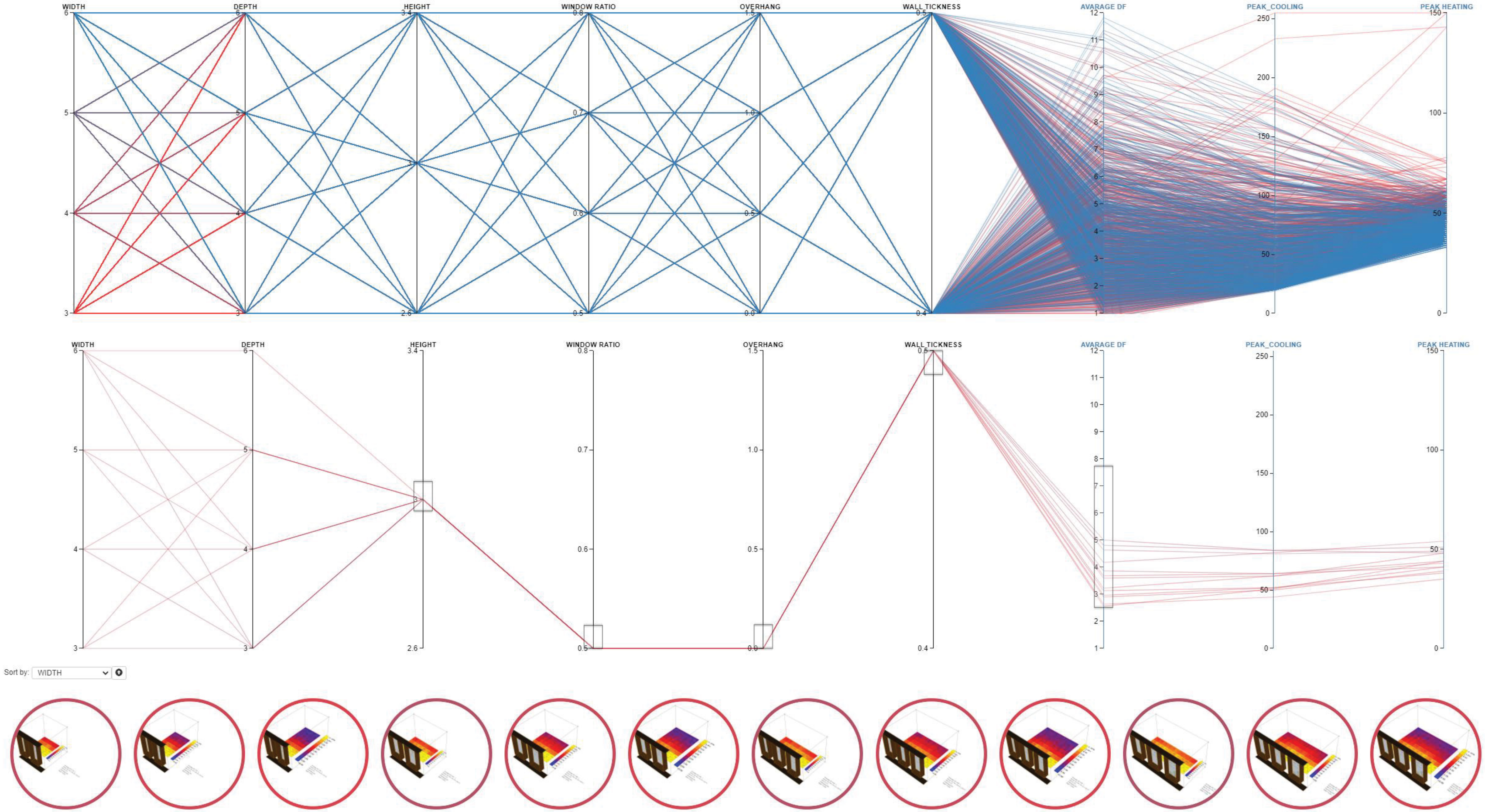
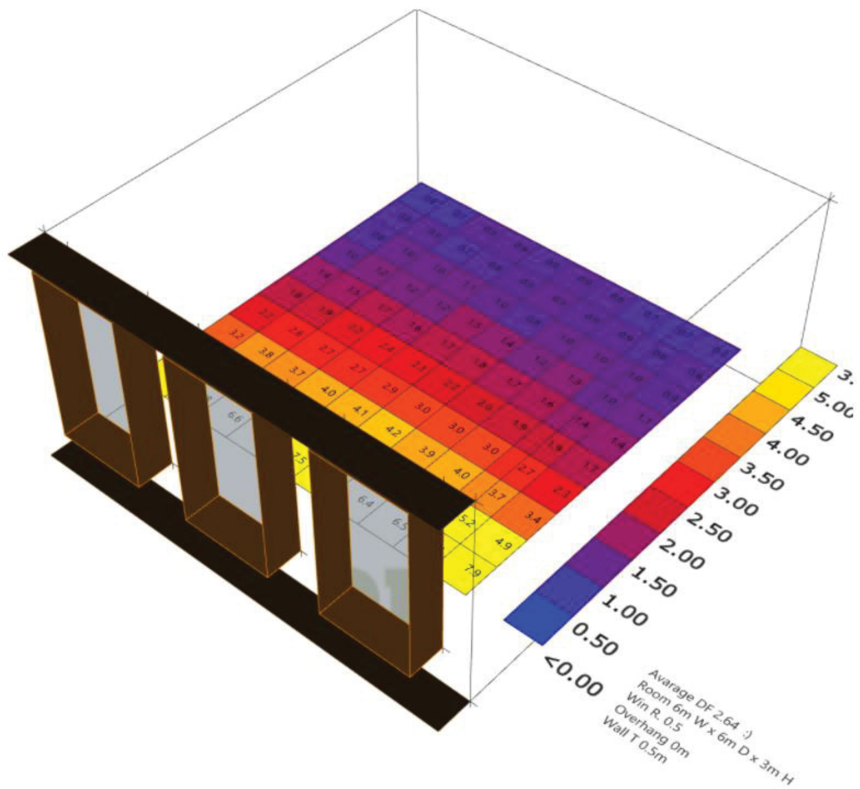


Figure 37 Daylight factor analysis done in Rhino, Grasshopper. Data visualization from Design explorer Link https://bit.ly/39kJqDh

The generated data, visualized in the Design explorer, gives an opportunity to select priorities and see outcome values. After trying out different combinations, I decided that minimum DF value in all rooms will be 2.5 %. It is possible to achieve a Daylight Factor of >2,5 % with window to wall ratio of 50% and wall thickness of 50 cm, if there are no obstructions from outside, like balconies, and the ceiling height is 3 meters. There are 2 or 3 windows per room with 2.2 m height to get more equal daylighting throughout the whole room. In end I was left with only 16 different versions, each for different room size. Use of the Design explorer gave me possibility to change some of parameters if selected run would not meet required daylight factor, as well I was interested to get similar results for all rooms. All results are visible on the Design Explorer platform at this link https://bit.ly/39kJqDh

The Best result



Average daylight factor of **2.64 %**

Room size – 6 m x 6 m

Ceiling height – **3 m**

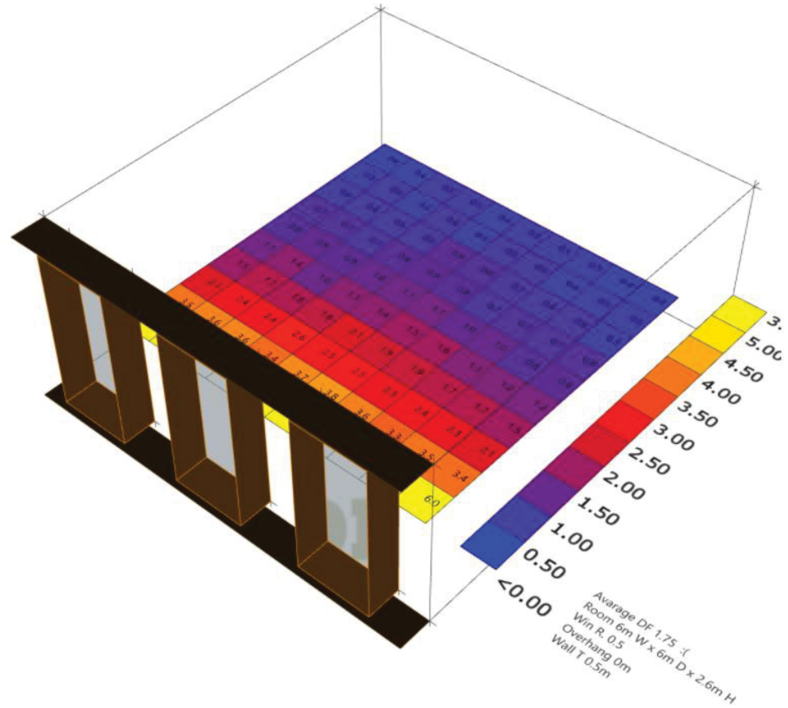
Window wall ratio – 50 %

Overhang – 0 m

Wall thickness – 500 mm

Optimal ceiling height is 3 m. Ceiling height of 3.4 m would provide better daylight factor and allow greater room depth, but this parameter would increase construction and operational costs.

Other



Average daylight factor of **1.74 %**

Room size – 6 m x 6 m

Ceiling height – **2.6 m**

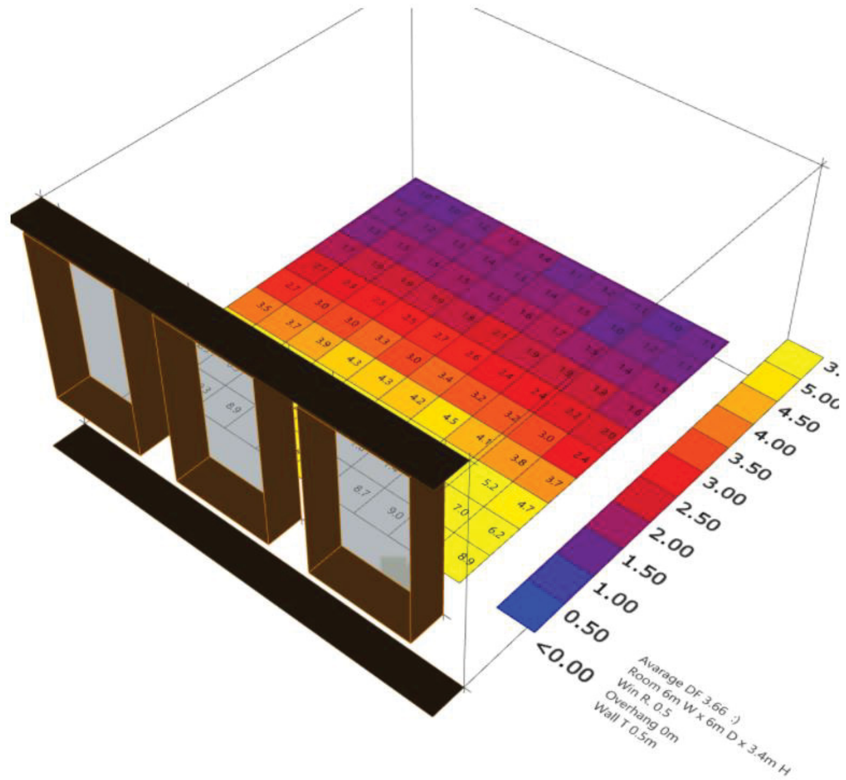
Window wall ratio – 50 %

Overhang – 0 m

Wall thickness – 500 mm

Standard ceiling height of 2.6 m will not have good daylight level indoors in 6 m x6 m room

Other



Average daylight factor of **3.66 %**

Room size – 6 m x 6 m

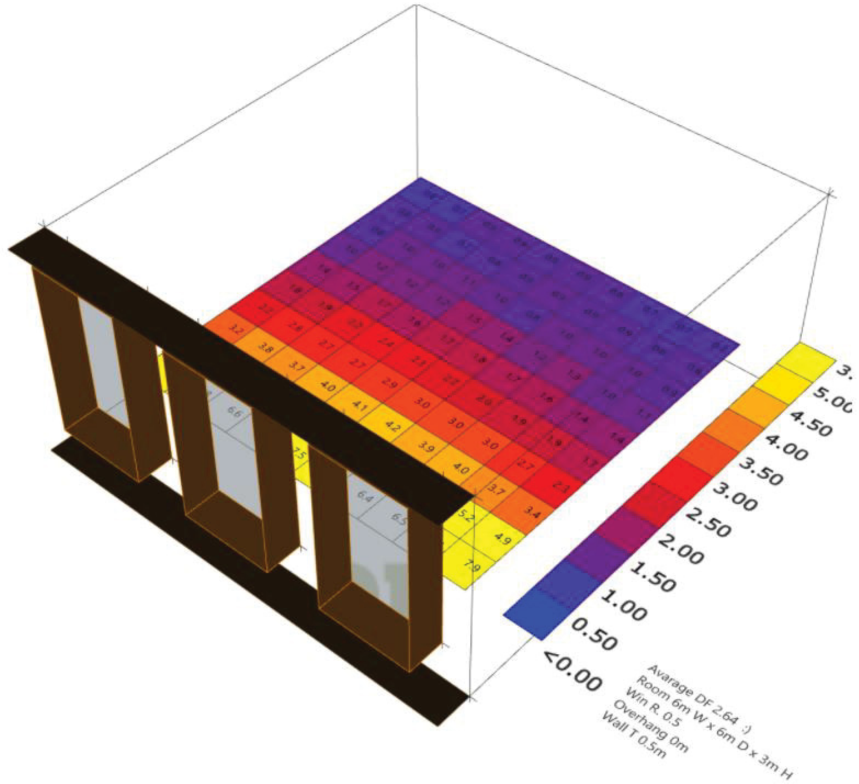
Ceiling height – **3.4 m**

Window wall ratio – 50 %

Overhang – 0 m

Wall thickness – 500 mm

Room depth could be increased, if ceiling height is 3.4 m.



Average daylight factor of **2.64 %**

Room size – 6 m x 6 m

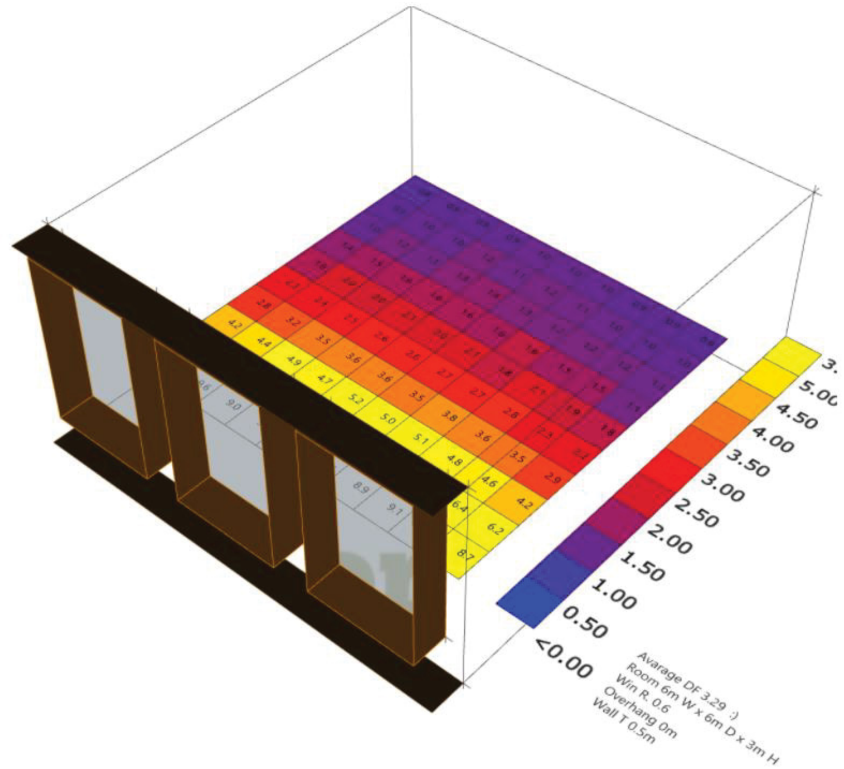
Ceiling height – 3 m

Window wall ratio – **50 %**

Overhang – 0 m

Wall thickness – 500 mm

Windows should be as small as possible, while meeting required daylight factor of 2.5 %.



Average daylight factor of **3.29 %**

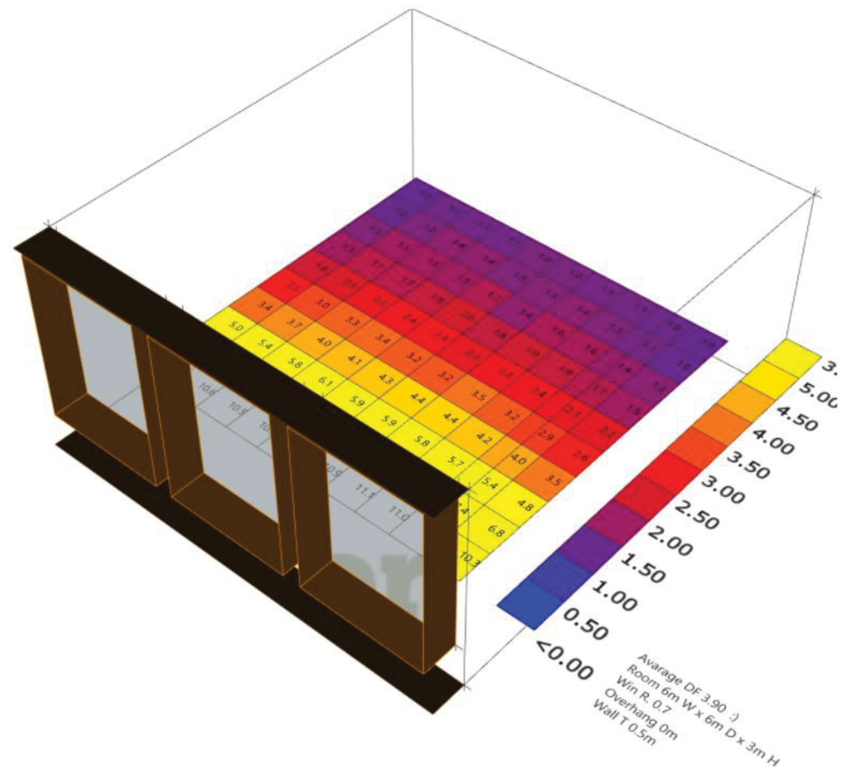
Room size – 6 m x 6 m

Ceiling height – 3 m

Window wall ratio – **60 %**

Overhang – 0 m

Wall thickness – 500 mm



Average daylight factor of **3.90 %**

Room size – 6 m x 6 m

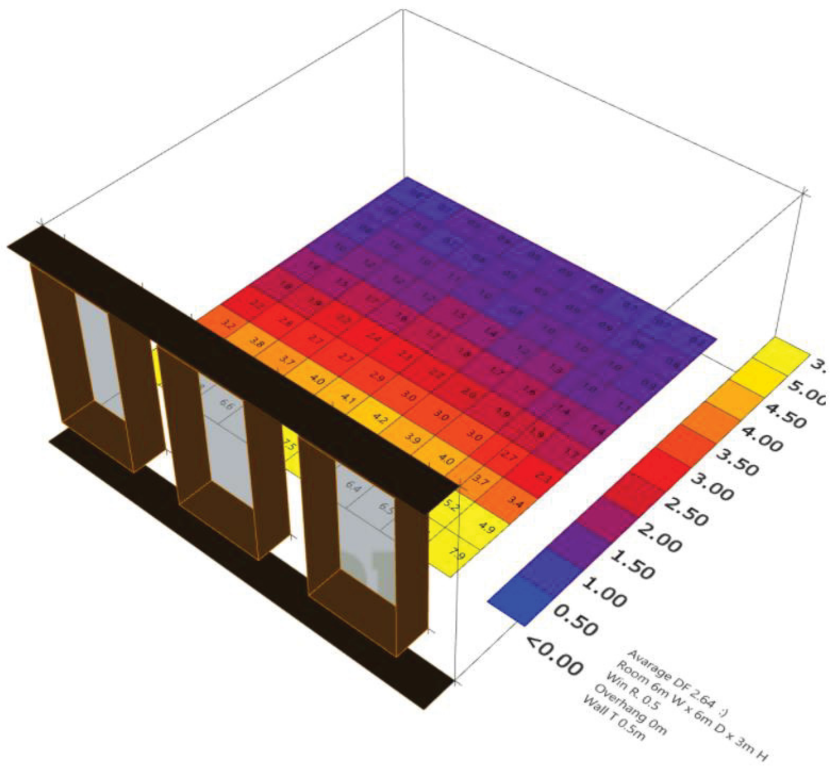
Ceiling height – 3 m

Window wall ratio – **70 %**

Overhang – 0 m

Wall thickness – 500 mm

Large windows can lead to room overheating and additional heat loss during winter.



Average daylight factor of **2.64 %**

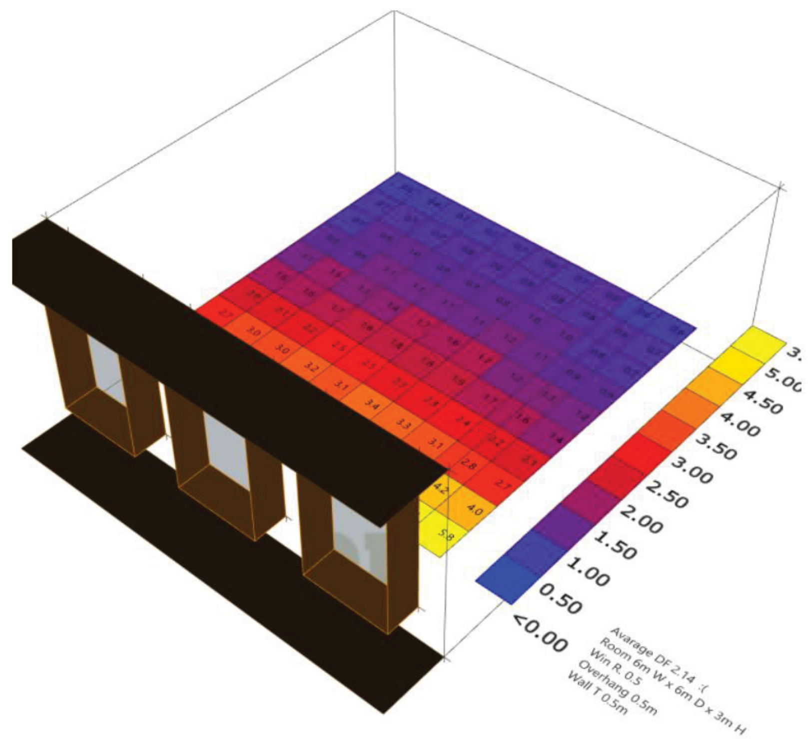
Room size – 6 m x 6 m

Ceiling height – 3 m

Window wall ratio – 50 %

Overhang – **0 m**

Wall thickness – 500 mm



Average daylight factor of **2.14 %**

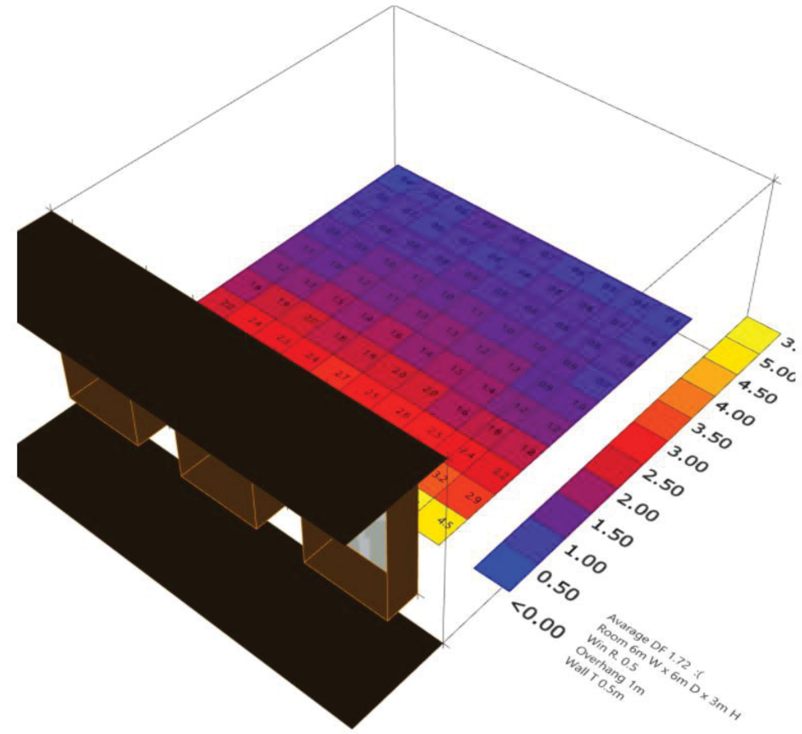
Room size – 6 m x 6 m

Ceiling height – 3 m

Window wall ratio – 50 %

Overhang – **0.5 m**

Wall thickness – 500 mm



Average daylight factor of **1.72 %**

Room size – 6 m x 6 m

Ceiling height – 3 m

Window wall ratio – 50 %

Overhang – **1 m**

Wall thickness – 500 mm

The new building`s design will not have external balconies on the street side, considering the natural lights shading effect of the overhang.

Small overhang of 50 cm blocks daylight entering room. This is an issue for rooms with 6 m depth.

Overhang of 1 m, size of small balcony blocks a lot natural light. In middle of the room natural daylight is not enough for reading and visual comfort. Artificial lights are expected to be used often.

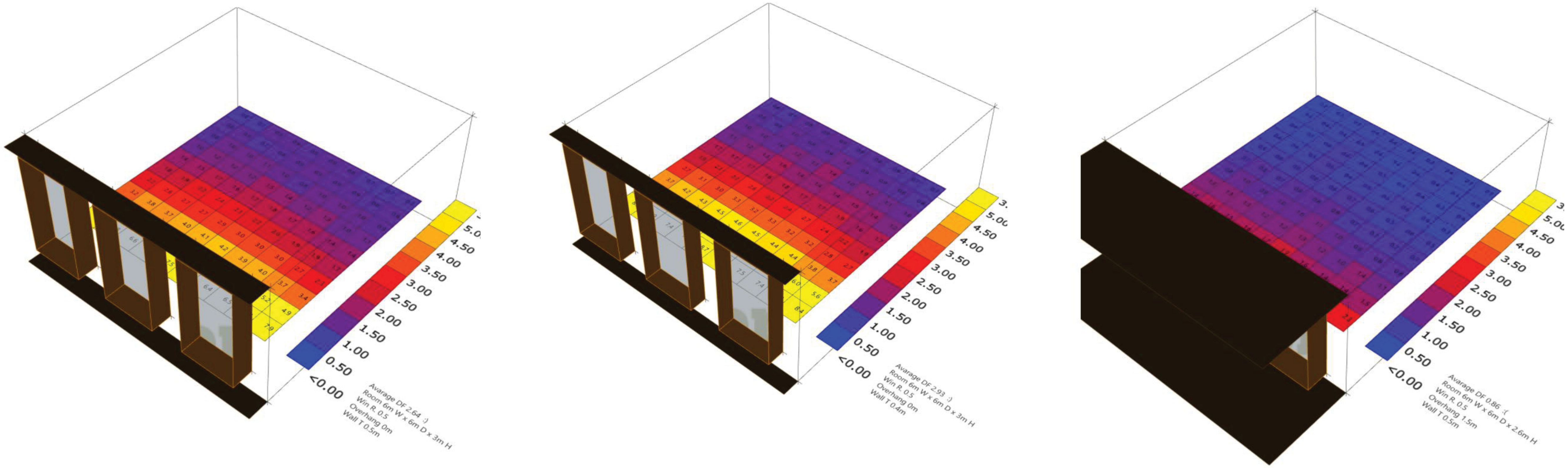


Figure 38 Daylight factor analysis done in Rhino, Grasshopper

Average daylight factor of **2.64 %**

Room size – 6 m x 6 m

Ceiling height – 3 m

Window wall ratio – 50 %

Overhang – 0 m

Wall thickness – **500 mm**

The wall construction of the new project consists of load bearing layer (CLT panels) and environmentally friendly, monolithic insulating layer (Hemp shaves mixed with sapropel). The wall thickness will be at least 500 mm, to meet required thermal values, therefore 500 mm wall thickness is selected for use in the New buildings design on Active house principles.

Average daylight factor of **2.93 %**

Room size – 6 m x 6 m

Ceiling height – 3 m

Window wall ratio – 50 %

Overhang – 0 m

Wall thickness – **400 mm**

Wall thickness leaves substantial impact on the amount of daylight indoors. If possible, wall thickness should be reduced or window opening made with rounded corners, allowing more light to enter room.

Average daylight factor of **0.86 %**

Room size – 6 m x 6 m

Ceiling height – 2.6 m

Window wall ratio – 50 %

Overhang – **1.5 m**

Wall thickness – 500 mm

In this version building has balconies in front of windows and ceiling height of 2.6 m (similar to the Base project). The calculated Daylight Factor level of 0.86 % is the same as in the daylight simulations done for the Base project.

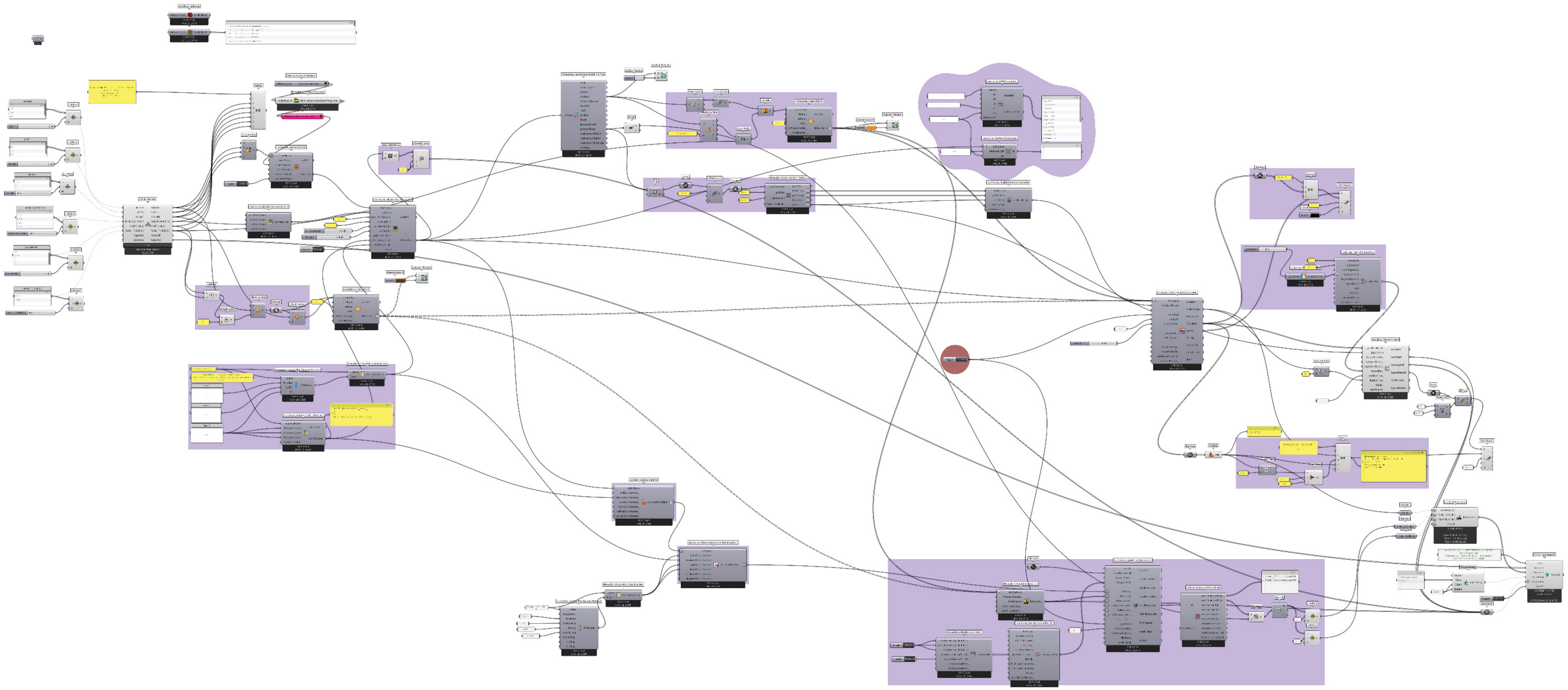


Figure 39 Rhino / Grasshopper script of Daylight analysis simulations.

Rhino / Grasshopper script with Ladybug, Honeybee and many other plugins were used to generate all the results for different room types. Collected The collected information and results where were placed in the Design explorer. This online tool helps visualize and analyze all runs together (see figure 37) and select suitable ones based on selected parameters (figure 38).

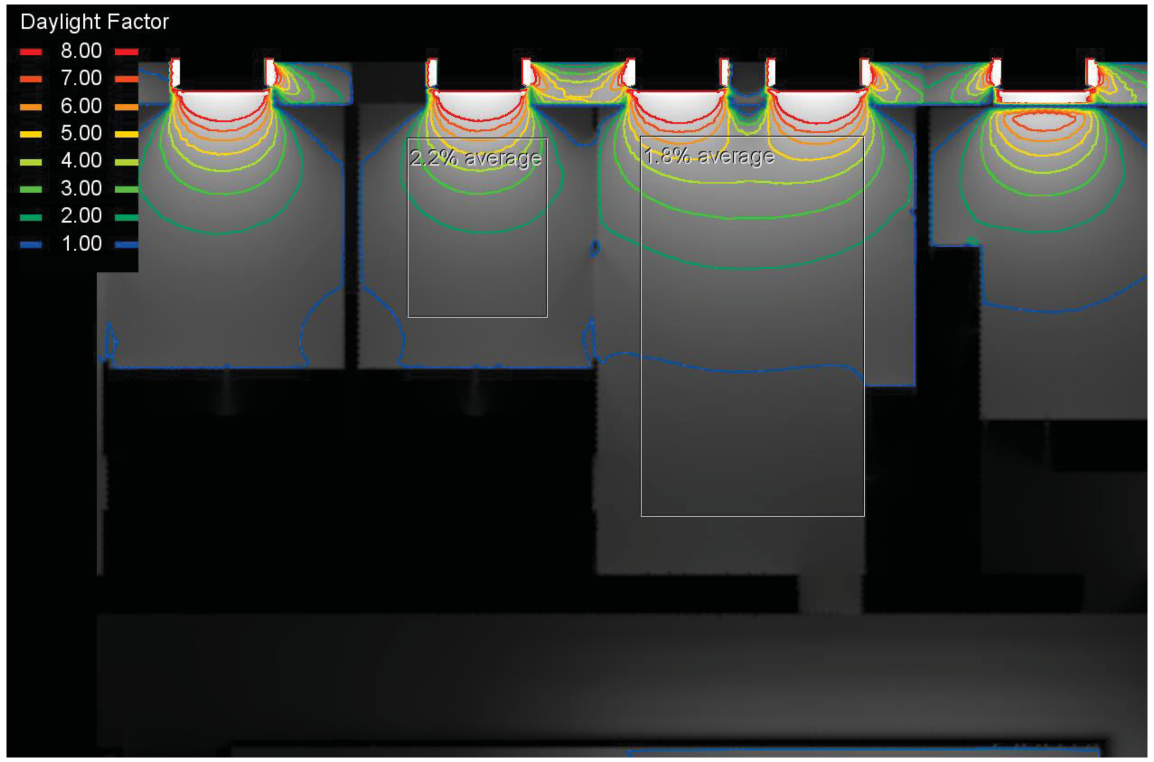


Figure 40 Apartment DF simulation from Velux Daylight visualizer 2

Figure 40 Apartment DF simulation from Velux Daylight visualizer 2 is a part of the 1st floor plan that has the lowest score in the Velux daylight Visualizer 2 simulation software. In the first floor, surrounding buildings are occasionally blocking direct sunlight entering rooms.

Velux daylight visualizer is used to calculate the final indoor daylight values. In this calculation the building`s surroundings, materials, geometry are taken into the account.

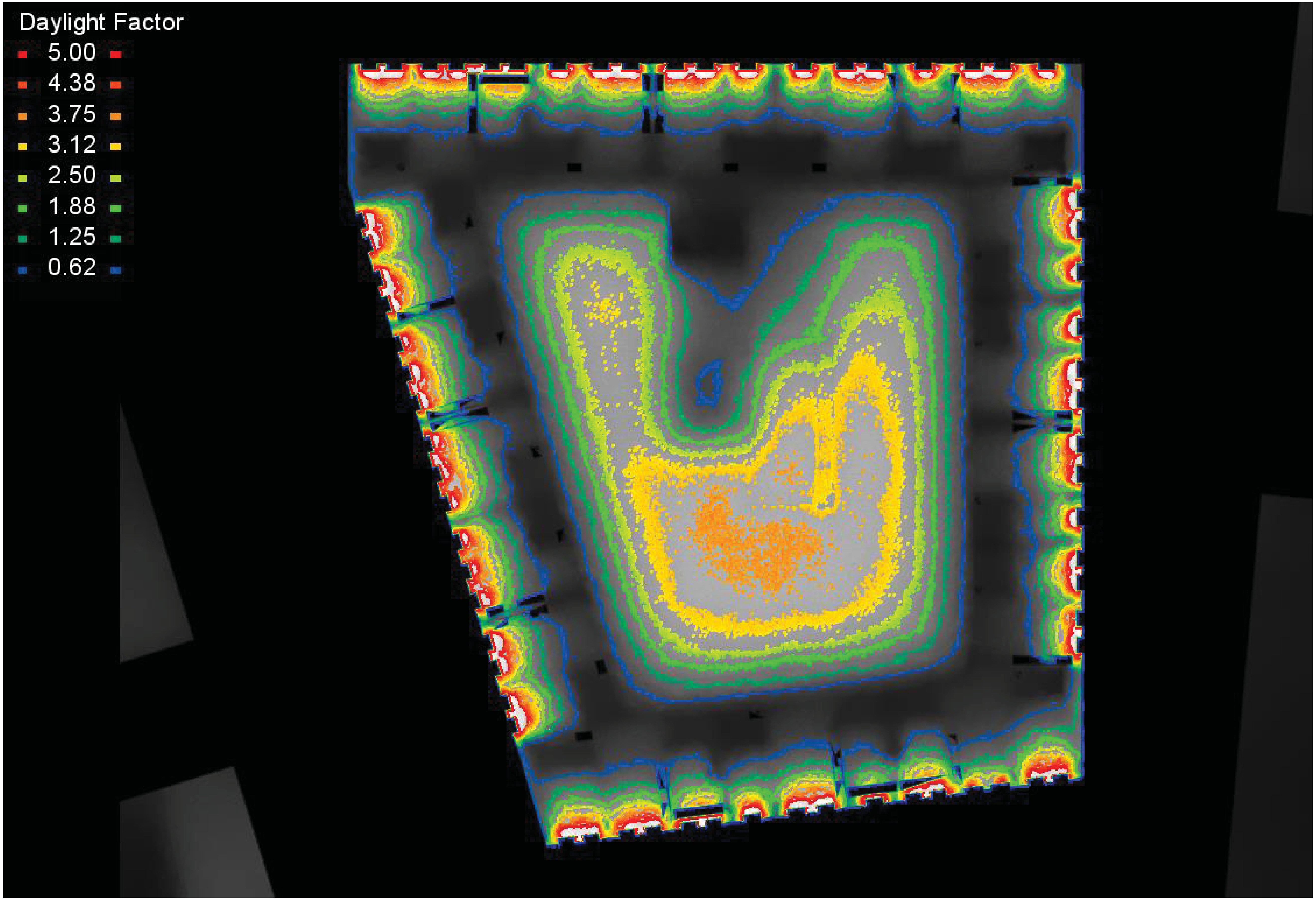
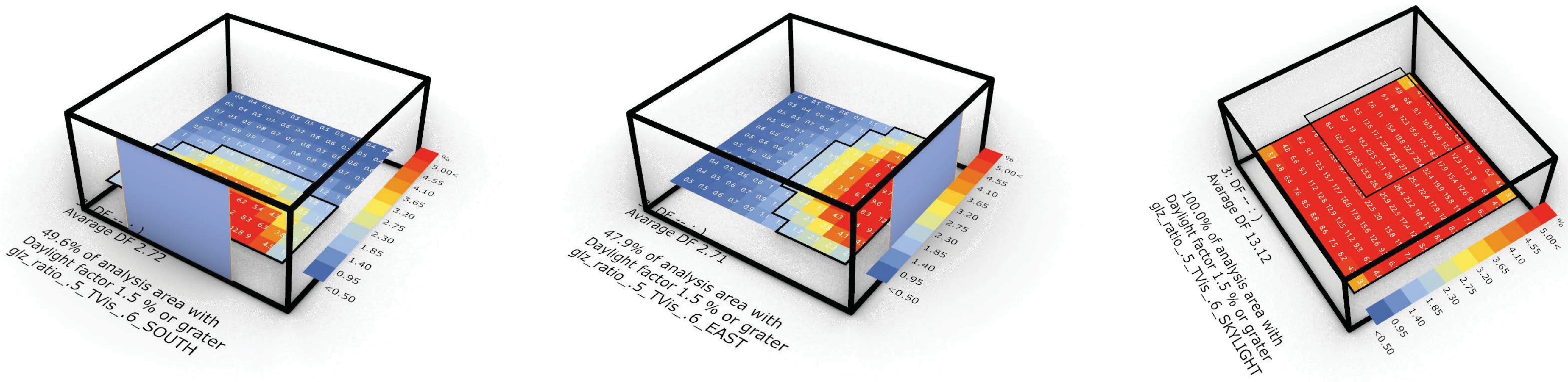
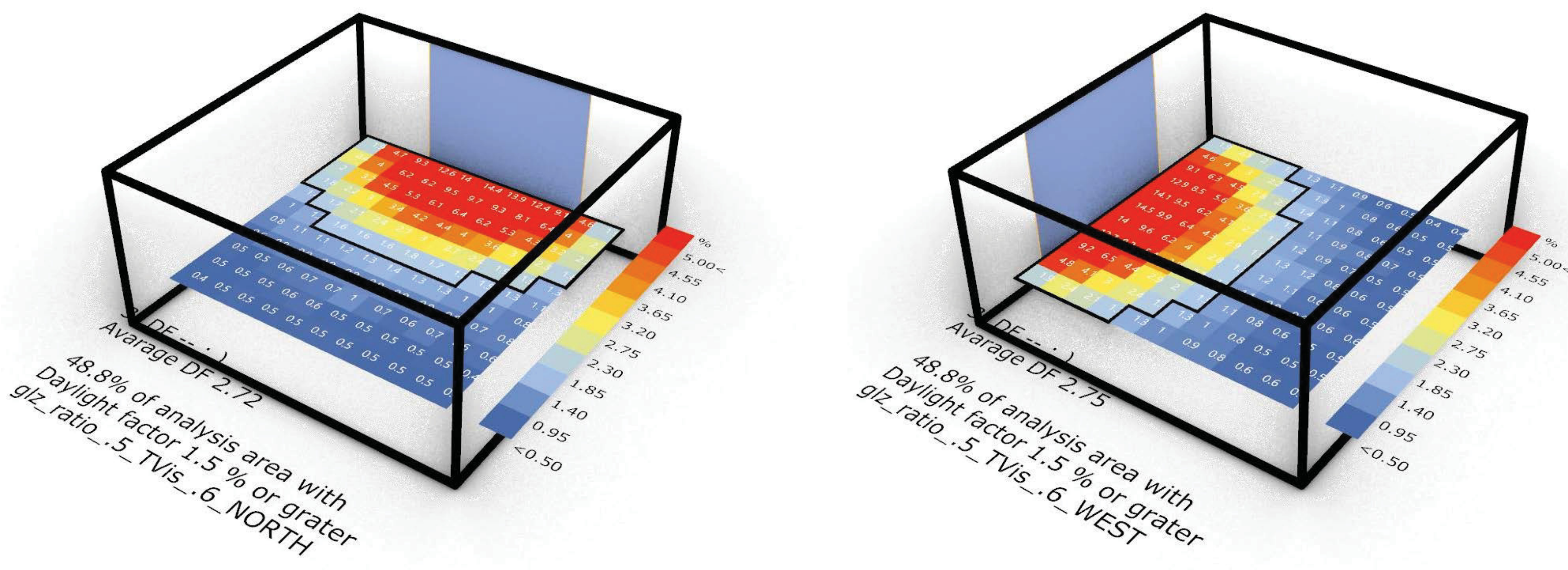


Figure 41 Floor plan DF simulation from Velux Daylight visualizer 2





The Daylight Factor is calculated with overcast sky that has equal sun exposure in all directions (Figure 36 Sky types) therefore room calculations have no difference in window positioning towards North or South. Even though skylights bring in considerably more daylight, unfortunately it is almost impossible to use skylights in multistorey apartment building.

Figure 42 Daylight factor study in Rhino/Grasshopper

2.6 Thermal Environment

The Thermal Environment is a very important factor influencing the comfort in the building. Comfort is a state of mind and personal preference. A person`s perception of thermal comfort is affected by the surrounding materials and their temperatures, air movement, humidity, and indoor air temperature.

Ideal thermal comfort is not a fixed set of temperature limits applicable to all people. We all have our temperature preferences and may desire variations in our Thermal Environment. Furthermore, we adapt to the Thermal Environment by removing our clothes or adding an extra layer, and our sense of Thermal Environment changes depending on the activities performed. Conditions that are too cold for reading might be just right for exercising or cooking. Psychologically we also adapt our preferences. On a winter day room temperature of 25°, C might be too warm but on a summer day, it would feel pleasant.

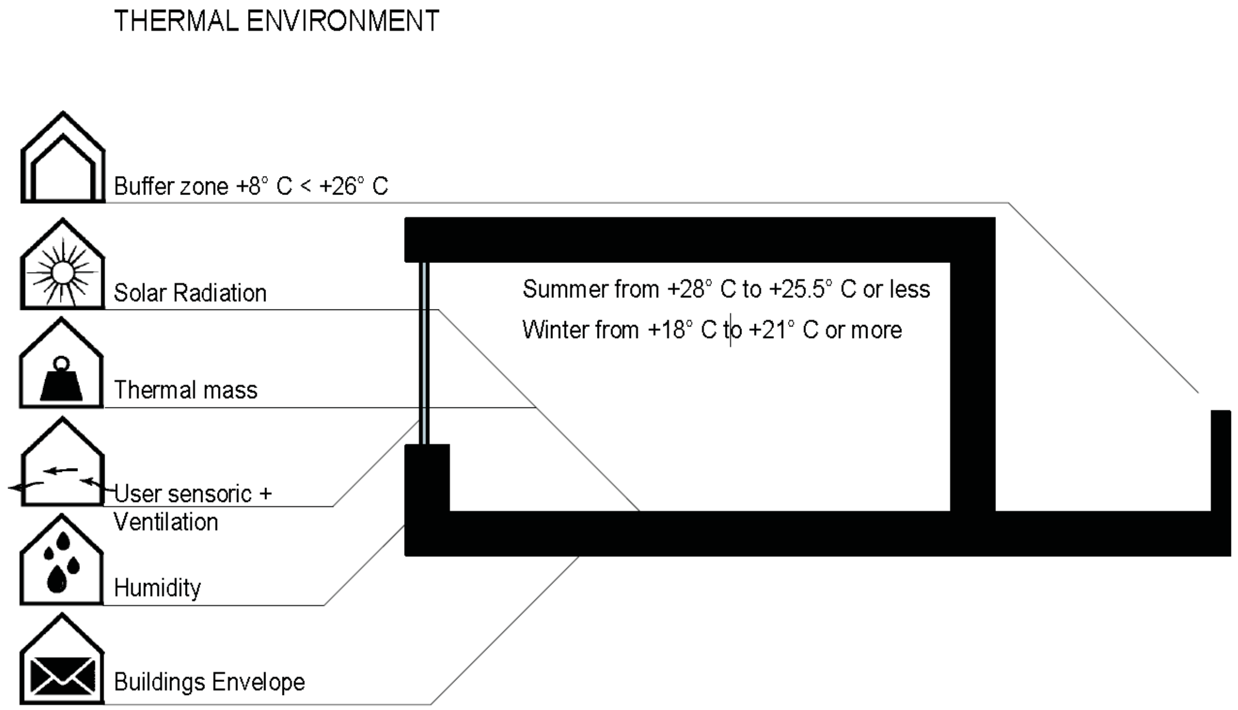


Figure 43 Thermal strategy for New design built with the Active house principles.

The Thermal Comfort can be characterized as an overall sensation experienced by humans considering all the influences on human beings in the indoor environment. Thermal properties cannot be regarded as a separate comfort factor, therefore the assumption of operative temperature with user ability to control climate is set as a thermal comfort factor.

- **Operative temperature** - The operative temperature is the result of the indoor air temperature and the average temperature of the indoor surfaces. To increase thermal comfort passive strategies are implemented in the design of the building.
- **Thermal Capacity** – Indoor materials with high thermal mass will reduce variation in temperature. All walls have laminated timber on the inside surface, floors are constructed from laminated timber with wooden flooring. Wood (pine) has a High Specific heat capacity - around 2000 J/m3-K depending on the material density, in comparison concrete has a heat capacity of around 2500 J/m3-K but is a lot cooler on touch and has high thermal conductivity.

- **Humidity** – The relative humidity level above 70 % indoors and wet indoor surfaces in combination with natural ventilation can help reduce indoor temperatures. Fortunately, in Northern Europe's climate zone humidification or dehumidification normally is not needed. The use of natural, breathable materials on the envelope of the building ensures migration of humidity through construction and passively regulates the indoor humidity level.
- **Solar Radiation** – Large windows are letting in the direct solar radiation that heats the surfaces and ensures a pleasant indoor climate for most of the year. During summer months, to avoid unwanted solar radiation, external blinds are used.
- **The Envelope** of the building – Controlled Indoor climate is dependent on separating the structure from the outdoor climate. The envelope of the building should prevent unwanted air leaks through the construction, and noticeable thermal fluctuations. A highly insulated, airtight envelope with the thermal mass on the inside is a basic requirement for a comfortable indoor climate.
- **Thermal Buffer Zones**– Closed central atrium, winter garden, or entrances with windbreaks serve as thermal buffers. Adjacent rooms to pass through, that gradually connect the inside climate with the outside climate, reduce unwanted drafts and thermal gains or losses. In the winter the covered atrium maintains temperature of > 8 ° C and in the summer the solar panels in the roof glazing provide shading while automatically operable openings let hot air out from the atrium. This zone is a transition space where people can adjust their clothing layers.
- **Ventilation**- During the summer months, fresh air movement provides a pleasant cooling effect. It is important to allow optional natural ventilation with a ceiling fan during the summer months. In the design, a mixed ventilation system is used – once a window is opened the mechanical ventilation for the apartment stops.
- **Outdoor Environment Impact** – The visual comfort from connecting with the outside climate adjusts the individual thermal comfort level. The occupants of the building unknowingly adjust their thermal preference to suit the climate outside.

Indoor thermal comfort remains an Active House Radar criterion that is hard to simulate and adjust for the needs of each individual. Maybe in the future, we will be able to create microclimates that work for every person and adjusts dynamically for their needs but currently, it is still guesswork with making assumptions about what would work for most people. Therefore, the design considers the suggested thermal passive strategies and gives the ability for the user to adjust the thermal climate, via increasing heating, ventilation, or opening windows and blinds.

Active House - Indoor environment evaluation

Input parameters

Desciption of room	apartment
Date of calculation (DD/MM/YE)	22.05.2019.
Is the space mechanically cooled?	No
What is the outdoor CO2 concentration	400

Results

Thermal environment	
Maximum operative temperature	1
Minimum operative temperature	2
Indoor air quality	
Standard fresh air supply, overall	1
Standard fresh air supply, summer	1
Standard fresh air supply, winter	1

Figure 30 Thermal Environment and air quality results from Active House tool

2.7 Indoor Air quality

A human inhales 15 kg of air per day on average, in most cases 90 % of this air comes from an indoors environment. Air pollution in most cases is associated with outside pollution: smog, pollution particles in the air from combustion engines, and house heating systems. However, indoor air in most cases is more polluted than the outside air. Some pollutants arrive with new furniture, some can be found in bed mattresses, cleaning products, some are in the materials of our buildings - in the wall and ceiling paint, material finishes, and even appliances. People with asthma and other illnesses often are more sensitive to indoor air quality. Others might experience long term negative effects on their health caused by poor indoor air quality.

In response to the pollution from building materials, many national and some interna-tional la-bels have been created. International label Cradle to Cradle (C2C) and national labels, like Finnish M1, Danish Indoor Climate Label, and the German AgBB and GUT labels are given to materials that have minimized or eliminated pollutant emissions from materials.

There are different types and pollutants within the indoor space:

- Moisture from washing, cooking
- Carbon monoxide (CO) from fireplaces and smoking
- Volatile organic compounds (VOCs) from aerosols and formaldehyde in furniture
- Allergens from house dust mites
- Carbon dioxide (CO2) from humans and indoor combustion processes
- Odors from pets, humans, food

All the pollutants should be minimized, those that are still present are removed via ventilation. CO2 levels indoors in comparison with the outdoor CO2 levels are a good indication of how effective the ventilation is. Humans are the main CO2 source in the indoor air thus ventilation should work with increased efficiency when humans are present, simultaneously removing other pollutants from the room. Active House Label requires indoor CO2 levels to be less than 500 ppm + outdoor level to get maximum rating. The minimum requirement is to have 1200 ppm + outdoor CO2 level.

Demand controlled hybrid ventilation with heat recovery will often be the most energy efficient solution for residential buildings. Since hybrid ventilation consists of both mechanical and natural ventilation systems, the design of the house should accommodate both. Mechanical ventilation should have indoor and outdoor CO2 sensors, window sensors. Natural ventilation is optimized for cross ventilation with ceiling fan.

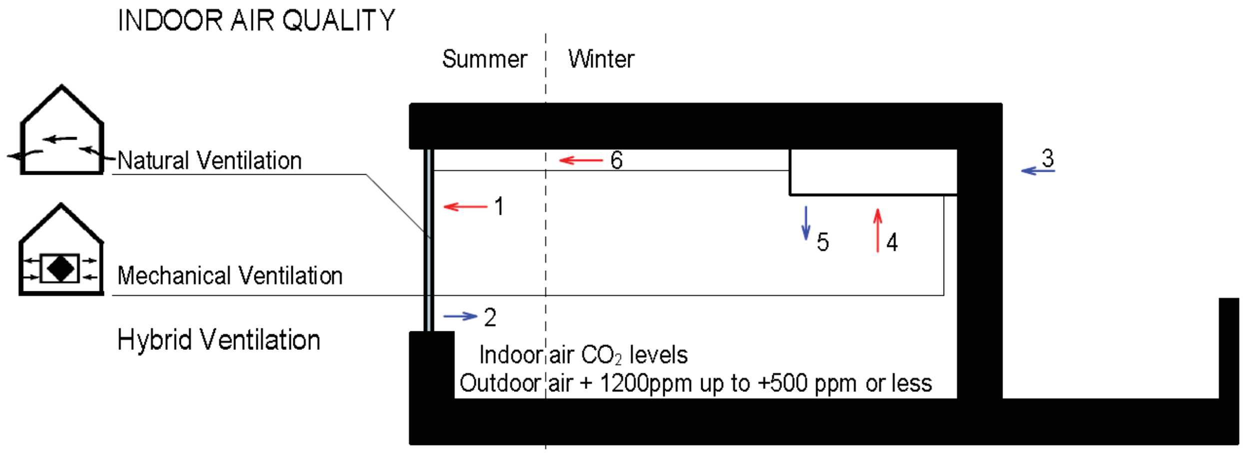


Figure 44 Indoor air quality strategy of new design.

In the project, to meet this demand, every apartment is equipped with their own Ventilation unit with heat recovery. Ventilation unit must actively monitor CO2 levels in all rooms and adjust airflow accordingly. CO2 sensors not only help to maintain constant quality of indoor air but as well they help to reduce energy load by reducing airflow during low occupancy time and increasing it only when it is needed.

As one new strategy connected with ventilation and energy saving is window automatization. Windows are automatically opened when CO2 level indoors reaches predefined point and they are closed when heat or cold stress is introduced in indoor space. This concept seems less applicable in this project, considering amount of days when in Helsinki region outdoor temperature is suitable for natural ventilation. Therefore, windows should be equipped at least with switch that connects with mechanical ventilation. In case window is opened mechanical ventilation is switched off.

Other strategies that were implemented in the building to meet high indoor air quality criteria with low pollutant levels (CO_2 level of + 500 ppm from outdoor air):

- Materials used indoors and furniture should have labels that verify pollutant free content.
- CO2 sensors connected to ventilation system to ensure constant indoor air quality.
- By removing the washing machine from the apartments and placing it in the communal laundry room, the moisture pollution is reduced in the apartments.

- It is easier to provide adequate indoor air quality by minimizing number of people in small rooms. Therefore, a larger common room in the building`s upper floor is created, where larger gatherings could take place.

2.8 Energy demand

The aim of an energy-efficient design is to create a comfortable and healthy indoor climate that requires a minimum amount of energy for the building to operate. The total energy demand in an Active House includes the energy needed for heating, cooling, lighting, ventilation, hot tap water and other equipment. The key for high energy performance is to reduce unwanted energy loses, so that a smaller energy supply could satisfy all needs.

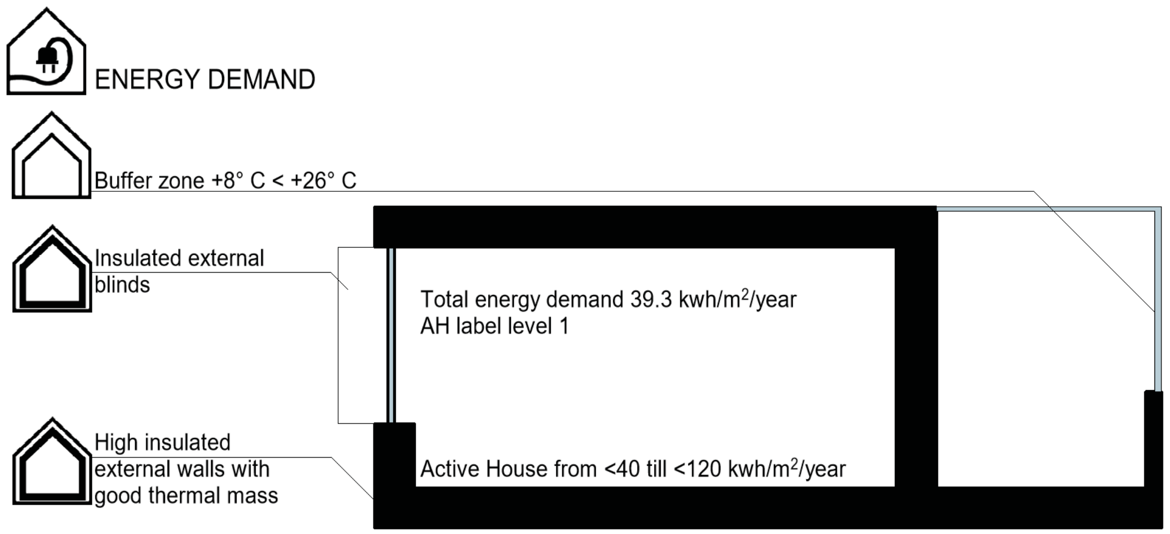


Figure 45 Active House energy demand strategy for new design.

The most cost-efficient way to achieve this is to use an integrated energy design from early-on in the design stage. This means that the focus is on “prevention before cure”. All elements: construction materials and equipment, are evaluated and determined in the early design stage. Impact of passive strategies like solar gain, natural ventilation, solar shading, thermal mass is estimated and implemented in design process and only then followed by integration of renewable energy solutions.

- Strategies implemented to reduce buildings energy demand:

- Envelope`s materials –Wood used in construction has a great thermal mass that eliminates thermal phase shift during 24 h time. Hemp sapropel mix provides not only good insulation values but also creates a monolithic airtight layer.

- Triple glazed windows with external insulated blinds reduce energy demand during night and the time when the apartments are not occupied. With the insulated blinds, the window construction has thermal conductivity of U-value of 0.4 W/m^2K but without 0,7 W/m^2K. Blinds could be applied during the summer to avoid unwanted solar radiation gain. The insulated external binds compared with internal blinds do not have condensation risk. External automated blinds are often used in hot climates, Span, Portugal, Italy, energy calculations show that they could be adopted in Cold climate as well.

- There is potential for saved energy by automatizing energy flow in the building. Automatic operation of the blinds would introduce energy savings on space heating and cooling by closing windows during night and time when the apartments are not occupied. Ventilation and window automatization in similarly would reduce energy expenditure needed for ventilation. Windows and ventilation can be operated to achieve energy savings without compromising on indoor air quality or thermal climate.

- Automatization in connection with solar panels- During daytime, when the building is with low occupancy level, most of energy is produced from solar panels. This energy could be directed to the heating and cooling of the space. In the evening, when the building is mostly occupied, energy from thermal mass is released, therefore minimizing the need for heating and cooling in the dark period of daytime, when there is no solar energy production.

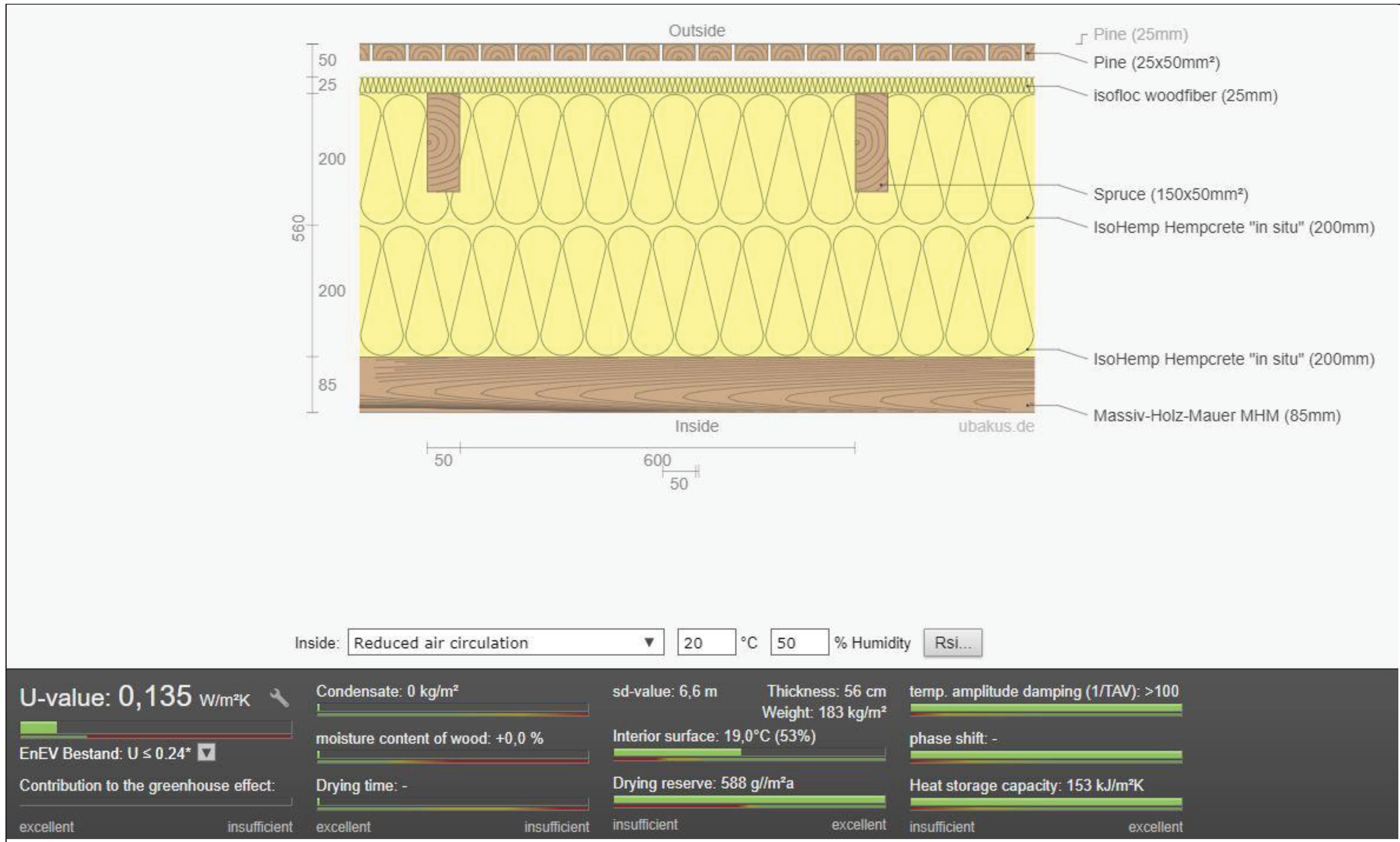


Figure 46 Active House Wall construction Analysis indicate that there will not be problems with condensation formation in constructions and that the structure has good thermal values

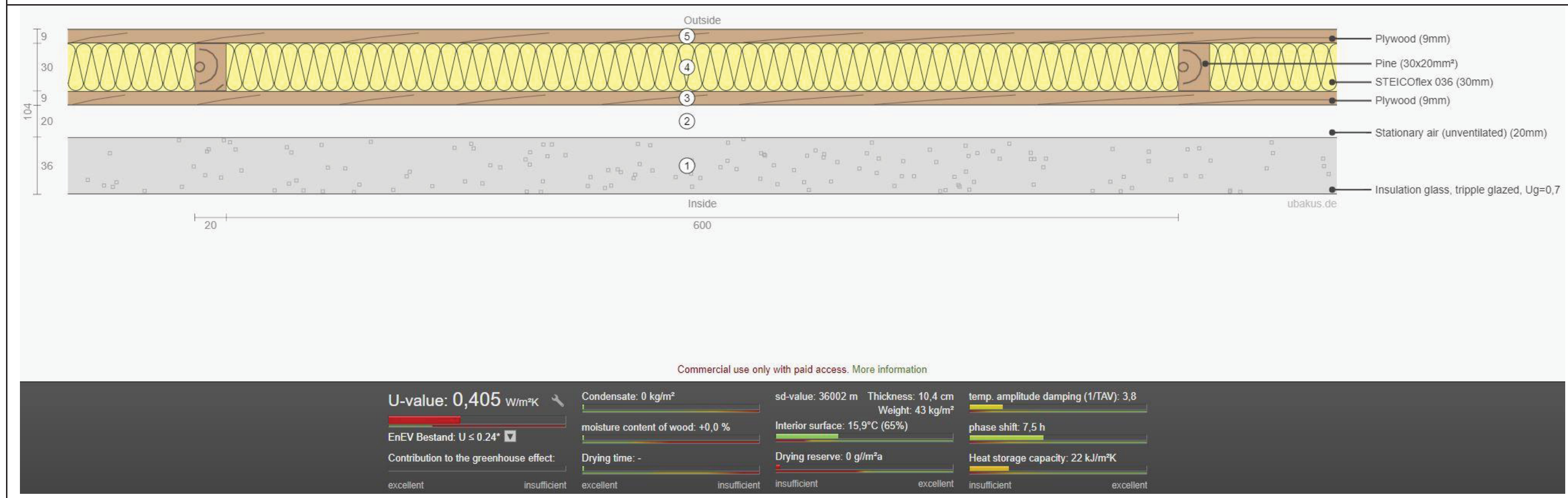


Figure 47 Building's construction element Thermal value and condensation calculation with online tool https://www.ubakus.com/en/r-value-calculator/

Insulated external blinds used in front of the windows have ability to bring down heat loss from windows during night and during the period when the space is not occupied- like daytime when most of building`s residents where not there.

Blind use will give more privacy for residents, provide completely dark period during night, increase sound insulation during night.

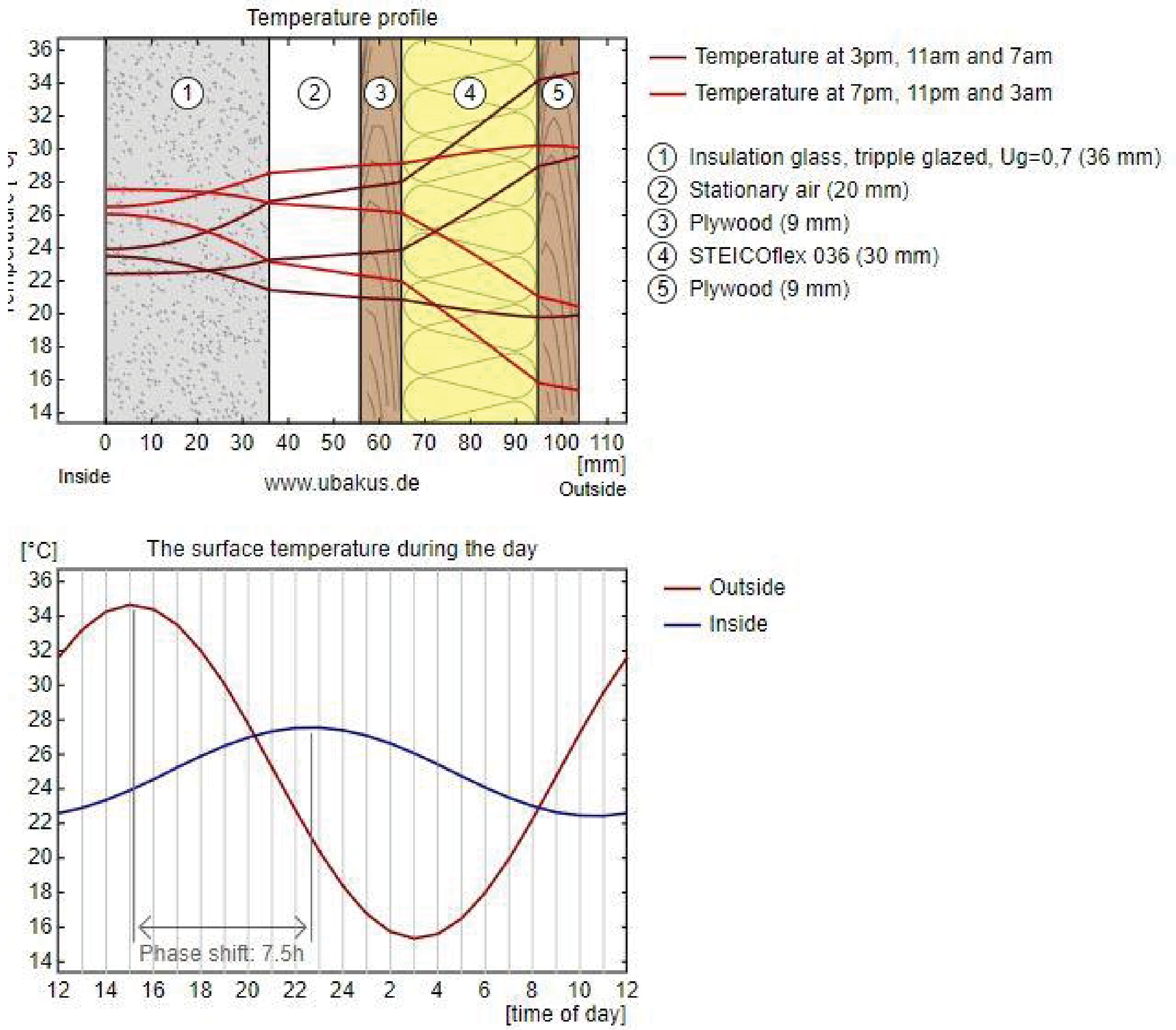


Figure 48 Active House windows with blinds phase shift analysis

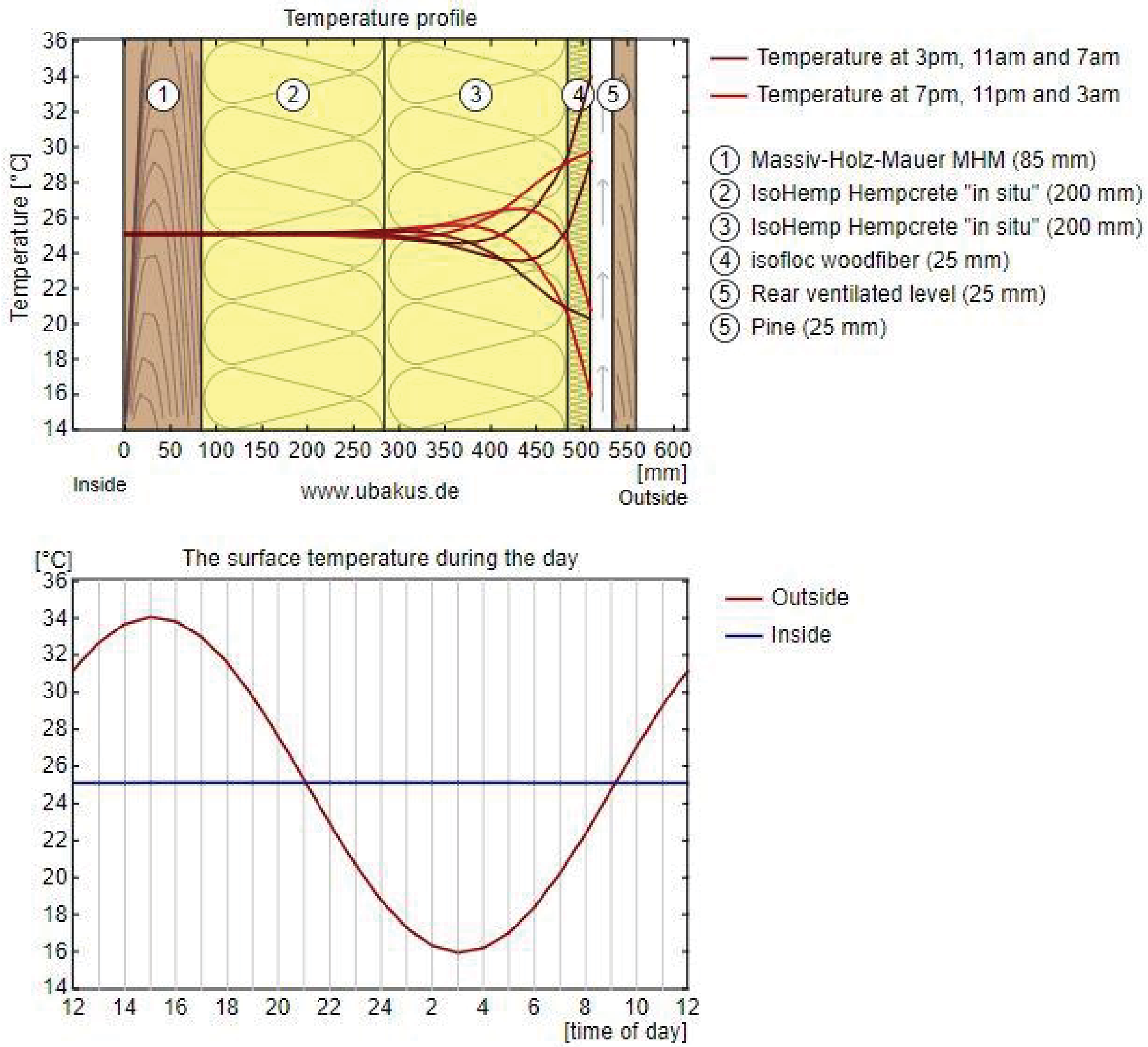


Figure 49 Active House wall constructions phase shift analysis

To meet the criteria of the Active House Label, buildings total annual energy demand should be under 120 kWh/m2. Building with annual consumption under 40 kWh/m2 meets highest rating of Active House Label in energy demand criteria. Locally certified tool should be used for energy calculation, in this case Passive house calculation tool PHPP 8.5 is used. According to calculations, the new design meets the highest criteria in Active House Label with annual energy consumption of 39.3 kWh/m2 , in comparison to the Base project with the total energy consumption of 74.2 kWh/m2/year

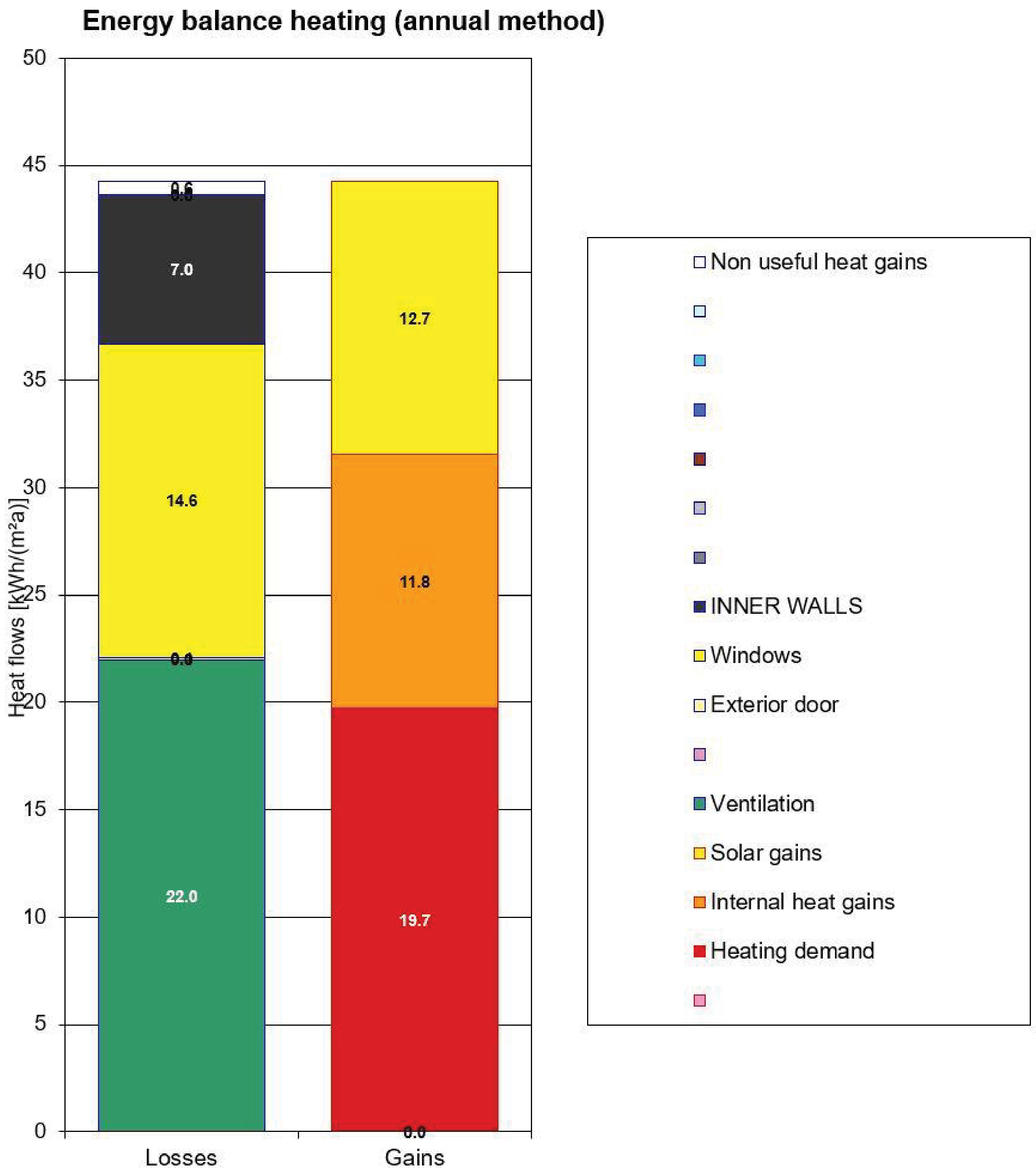


Figure 50 Active house energy balance graph from PHPP 8.5

Active house energy consumption results in passive house calculation tool PHPP v8.5

Heating demand is reduced due to improvements in heat loss from external wall constructions and windows. Ventilation demand is reduced due to smaller, more efficient ventilation units.

2.9 Energy supply

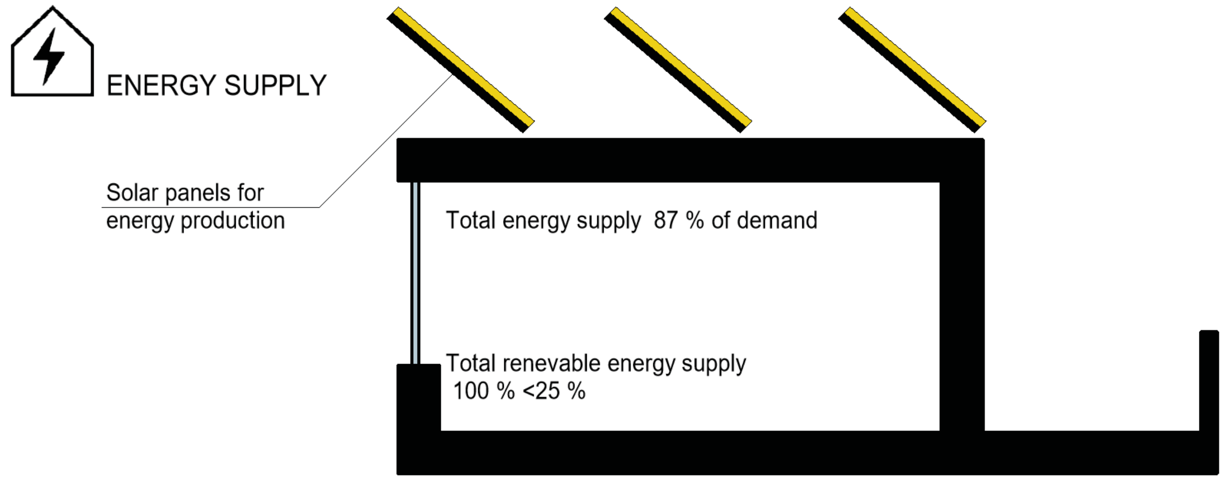


Figure 51 Active House energy supply strategy

In an Active House, the energy demand for the building must be lowered as much as possible using passive energy saving strategies, while the resulting small demand should be supplied in the most sustainable and cost effective way depending on what energy sources are available in the building, in nearby system or in the grid.

As much as possible an Active House should use renewable, local energy, like, electricity from wind turbines or photovoltaic cells, solar thermal energy, hydropower or biogas. Non-renewable energy sources are usually of fossil origin, such as coal, gas, oil and nuclear.

Supplied energy in building is used for space heating or electricity production. In Active House label it is required to use at least 25 % of renewable energy, and in the best-case scenario all energy demand is satisfied by renewable energy production. In the Base Project there is 13 kWh solar power system on roof that produces annually 10 500 kWh of energy or 3 kWh/m^2 of 3500 m^2 building. These values gave Active House energy supply score of 4, that is lowest acceptable score for energy supply.

In order to improve Active House Radar on energy supply criteria all roof of new design is covered with solar panels. The roof above apartments hosts 210 photovoltaic panels with calculated systems power of 66 kW, that produces annually 63 000 kWh of electricity. Glazed atrium has integrated photovoltaic cells in glass providing additional 37 000 kWh/annually. In total, annual energy supply from PV panels would be 34 kWh/m^2 that with a lot lower energy demand would make 85 % of energy demand satisfied with renewable energy from site.

Calculation - solar panel electricity output

New designs System with solar panels (S1)

Panel energy output E= 350 W

Number of panels N= 210 pc

Systems efficiency C=90 %

S1=E x N x C / 1000 = 350x210x0.9/1000=66.15 kW

Solar cell glass roof (S2)

Solar cell energy output E= 4.35 W

Area coverage cells/glass R = 70 %

Solar cells in 1 m^2 N= 16 pc

Systems efficiency C=90 %

Roofs m^2 A= 760 m^2

S2=E x N x A x C / 1000 = 4.35 x 16 x 760 x 0.9 / 1000 = 47.6 kW

Annual energy Production

Rentable space GA = 3325 m2

Annual Yield from 1 kw system Y= 1000 kW

Total annual energy production S = (S1+S2) x Y / GA = (66.15+47.6) x 1000 / 3325= 34.2kWh/y/m^2

PV energy production with slope 0 degree = 784.13 Wp

PV energy production with slope 30 degree = 960.32 Wp

PV energy production with optimized slope of 43 degree = 977.26 Wp

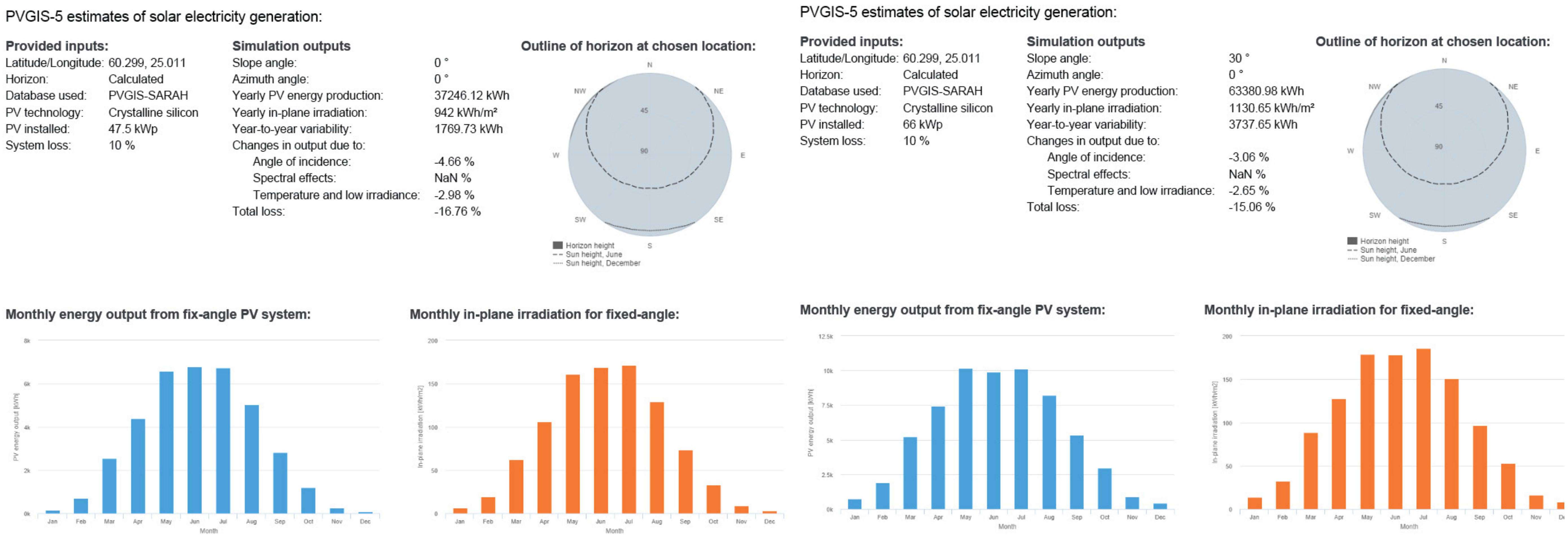


Figure 52 Solar panel systems annual energy productions calculations results for The Active house. Calculations done in online tool PVGIS-5, https://re.jrc.ec.europa.eu/pvg_tools/en/#PVP

Energy required for everything: for food, our daily commutes, and maintaining hygiene. By using solar energy to locally produce food and decrease our commuting needs with finding possibilities to work closer to home, or even from home, we reduce the carbon footprint generated by our daily activity. Therefore, an important part of the New project is a hydroponic garden with a fish tank and working space in atrium. It is impossible to accurately measure the value of such strategies, however I believe that they contribute to the overall ethos of caring for environmental sustainability.

2.10 Primary energy performance

The Active House Label limits the use of fossil fuel and primary energy. The difference between the primary energy at the inlet of the production unit and the supplied energy is called conversion factor. Each type of energy supplied to the building has its own conversion factor that depends on many factors, like production-transport-distribution losses, as well as on the combination of natural resources used over this whole chain. For example, the conversion factor for electricity ranges in most countries between 1.8 and 2.7. District heating often has a conversion factor between 0.6 and 1.0, depending on the renewable energy content in the resource mix.

Energy demand - energy supply = Required energy
Required energy x conversion factor = Primary energy performance

In order to meet the best results in Active House Radar's primary energy criteria, building should produce more energy than it spends. If the building primary energy performance is higher than 30 kWh/m2 it will get the lowest score. For the Base project primary energy performance is 64.2 kWh/m2/year that meets lowest score of primary energy's criteria. The New project according to Active House radar has a primary energy performance of -4.7 kwh/m2/year that corresponds with the best result.

The Active House radar automatically calculates the primary energy performance, after inserting total energy demand and supplied energy. However, the results of Active House radar calculation raise some concerns, as the results do not match with the one's obtained from the described calculation method in the specification. Regardless of some variation in results, it is safe to assume that energy produced during daytime in many cases will not be needed in grid. Therefore, the building should be equipped with batteries to store the excess energy. For the building industry there are new developments in the battery technology (mechanical batteries, saltwater batteries). In this case the saltwater batteries could offer environmental benefits. Saltwater batteries are better suited for residential projects. Deep discharge, fast charging and they are not degrading if left completely empty or full for a long time, environmentally friendly materials used in the production. The disadvantages for the saltwater batteries are the large size and weight but this is not an issue for stationary energy storage.

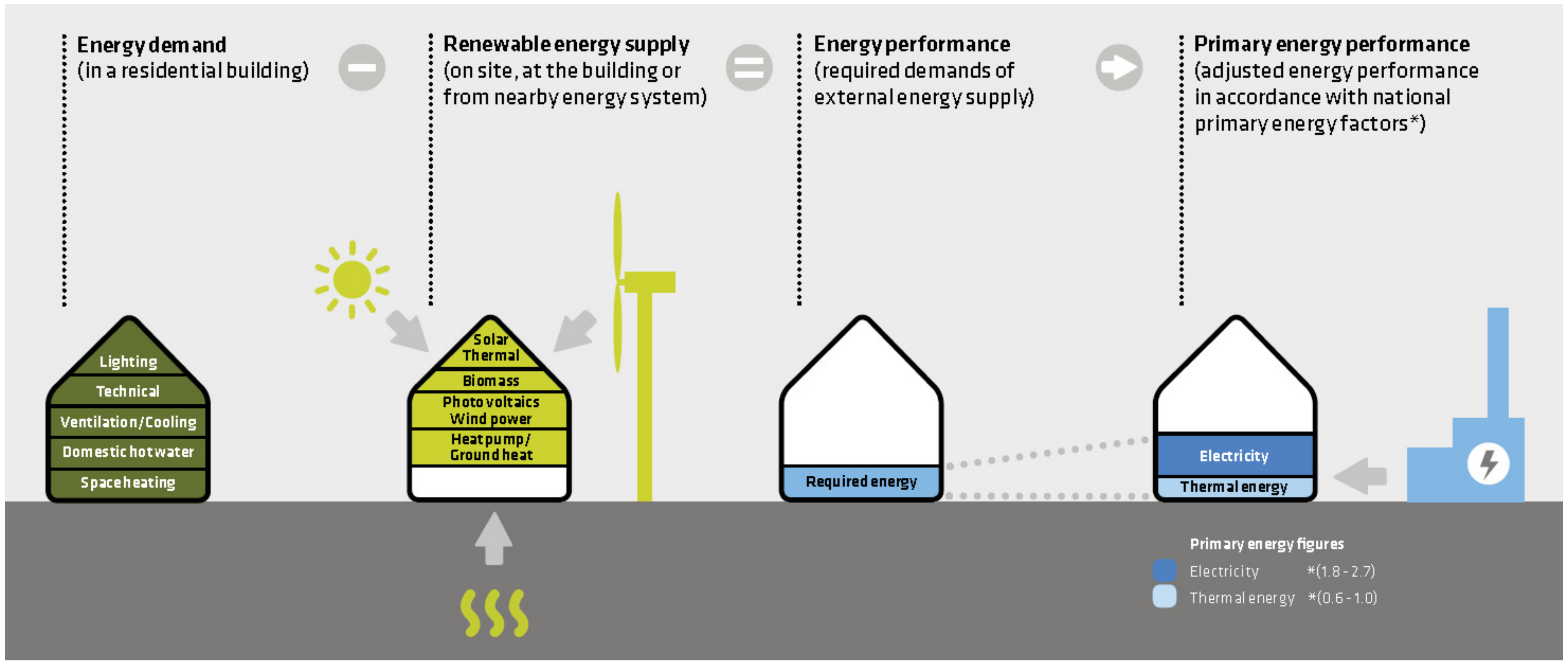


Figure 53 determining primary energy consumption

2.11 ENVIRONMENTAL LOAD

As explained in chapter 1.2 Built industry – biggest polluters , construction industry accounts for a large portion of the material use and energy associated with the material production. Construction industry causes a large portion of global pollution, therefore according to Active House Label, buildings should meet environmental load criteria.

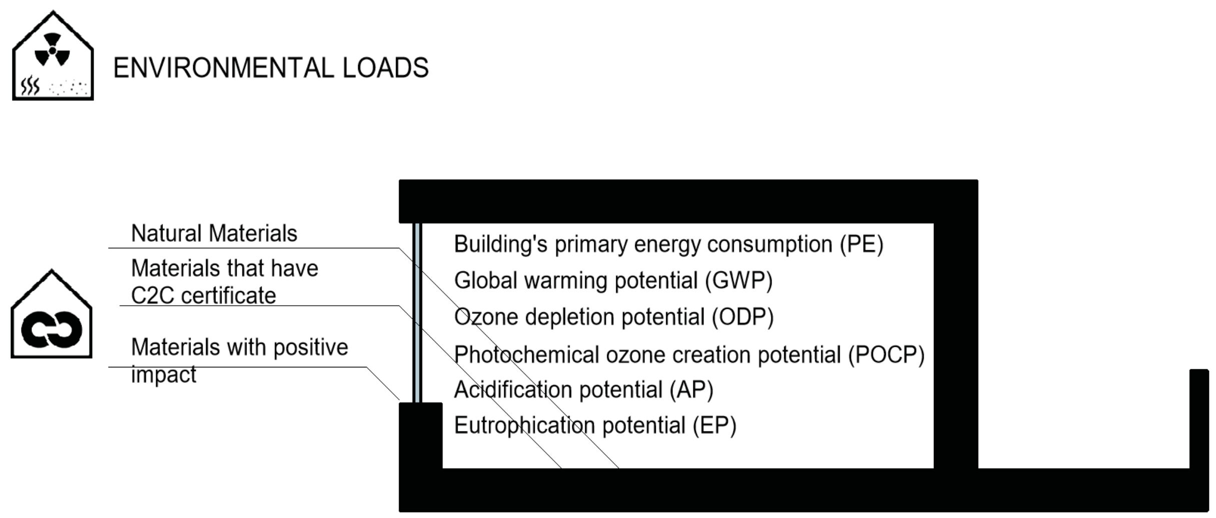


Figure 54 Active House environmental load strategy

According to the TC-350 standards (sustainability of construction works), the environmental loads are described by 5 different categories of emissions (equivalents);

- ozone depletion R11-eq,
- photochemical ozone creation potential $C3H_4$-eq,
- acidification potential SO_2-eq,
- eutrophication PO_4-eq,
- Global warming potential CO_2-eq
- Buildings primary energy consumption kWh/m^2

The Life Cycle Assessment (LCA) has positioned itself as one of the most widely used tools for environmental assessment of materials. The purpose of an LCA calculation is to calculate the building's overall environmental impact through its life cycle. An LCA calculation includes environmental impact from the product stage, construction process, use stage and end of life.

Design guides:

• Since the calculation is based on the environmental loads from the use stage and the construction phases, it is important to analyze both the use of materials and the embodied energy.

• Use the LCA calculation tool to analyze different materials for the building. Some building materials might have relatively high environmental loads, but also a long lifespan.

• Choose low-odor and low-emission construction products.

• Take the highest concern when choosing the construction materials with the largest mass (the heaviest materials).

• Choose construction materials that have recycled material in its content.

Environmental impact from buildings operation for 50 years accounts for more emissions than construction itself. Many materials and parts of construction might need replaced in the 50-year period. Comparisons between the Base project and the New design based on Active House principles do not include replacements and repairs done to construction during 50-year period. It is assumed that the construction will last for 50 years without any need for repair. The Base project uses a lot of prefabricated concrete, mineral and oil-based insulation materials, which are causes for pollution. However, the Life Cycle Assessment (LCA) calculation indicates that the Base project meets second highest result in Environmental load criteria with lowest result in buildings primary energy consumption during entire life cycle. In the New design I replaced concrete structure with Cross laminated timber structure and mineral based insulation with natural insulation made from hemp and sapropel. Changed materials provided small gain in the Active House Radar environmental impact criteria total score. To improve this result primary energy use should be reduced. In the Active House Radar primary energy use with

at least -150 kWh/m^2 gives highest result. Primary energy use is lower than 15 kWh/m^2 gives the second-best result.

Early versions of Excel tool (LCA 1.4) for calculation had some human errors of designing formulas that led to misleading results. This issue has been solved with latest update, but this raise concerns over precision of calculations that were done prior to the new version (LCA 1.5). It is still unclear how to achieve highest results in Active House Radar's criteria of Buildings primary energy consumption during entire life cycle. For now, my best guess is that to get negative value in primary energy, the building should incorporate a lot of reclaimed and recycled materials.

Results for AH radar tool

3.1 Environmental loads	
PE	24.4
GWP	-1.65
ODP	3.95E-07
POCP	0.0013
AP	0.0160
EP	0.0036

3.3 Sustanable construction	
Recyclable content	89%
Certified wood (FSC/PEFC)	99%
Verified EPDs	53%

Figure 55 Life Cycle Assessment results for Active house project.

Generated results from Life cycle assessment indicate slight improvement from base project

It is not clear how to reach best results in Primary energy consumption during entire life cycle that are **negative** -150 kWh/m^2

In base project GWP is negative indicating that building sinks mor CO_2 than produces during buildings life cycle.

2.12 FRESHWATER CONSUMPTION

This Active House Radar metric considers amount of water savings from local average. Freshwater is a limited resource on the planet. Much surface freshwater and even ground water is unsuitable for consumption, in fact, less than 1% of Earth's water is suitable for consumption. Therefore, freshwater could be considered as limited recourse.

Active House Label aims to reduce freshwater use in the building. For the best result according to Active House Radar chart, the building should implement strategies that help reduce consumption of fresh water by 50 % from national average. At least 10 % improvement from national average water consumption is required to meet the lowest criteria. As there were no indications of water saving measures in the Base project, I selected National average water consumption. With this value Base project would not meet the Active House Label criteria.

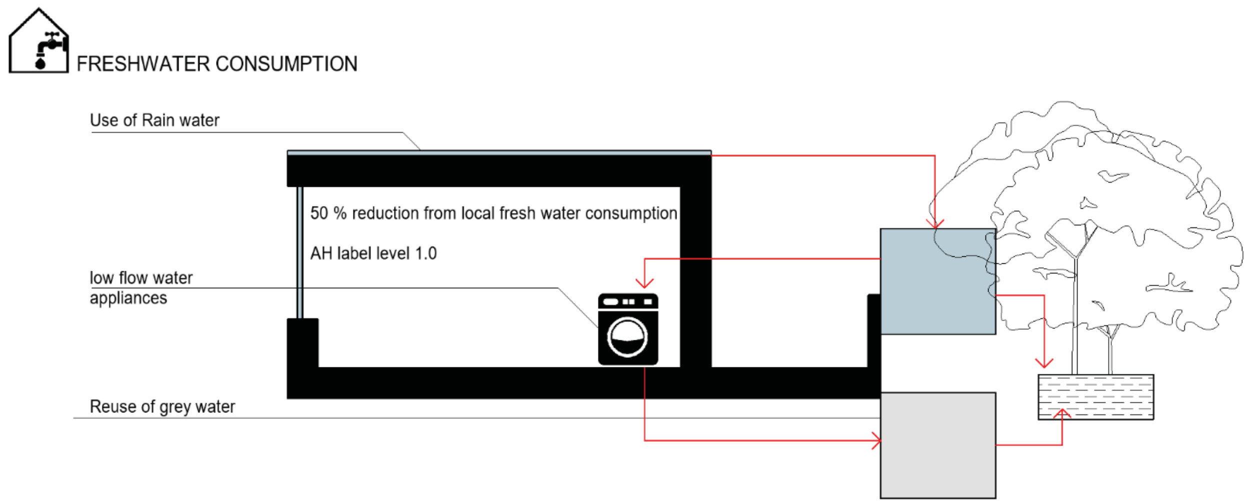


Figure 56 Active House freshwater consumption strategy

To meet the Active House Radar highest criteria, the New design implemented 3 step approach.

1. Reduction of water consumption - Water saving components: shower heads, taps, toilets, washing machines, dishwasher, should be used in construction.

2. Replacement of potable water -Rainwater can replace the non-potable water usage in the building. Rainwater could be used for toilet flushing, watering plants, washing machine and dishwasher use.

3. Recycling water - Grey water from showers, sinks and washing machines can be used in atrium plant irrigation

The part that will help to reduce freshwater use is rainwater collection. All rainwater is collected from the rooftops and stored in a water tank in the basement. Collected water is filtrated and used for a Hydroponic garden, watering plant boxes, connected to washing machines in laundry room, toilets, and dishwashers.

For each tap, enter consumption in liters/s or liter pr. tap in the green fields below. Relevent data can be found in product-datasheets
Datasheets must be part of the documentation given to the verifier, if the project is verified

Installation	flow [L/s] or liter pr. tap	tap-length [s]	number of taps / person / day	consumption / person / day
Bath(Shower)	0.15	300	0.8	36
Bath tube	0	600	0.1	0
Hand wash (Toilet)	0.1	20	3	6
Hand wash (Kitchen)	0.1	20	6	12
Dish washer	15	-	0.25	3.75
Washing machine	40	-	0.25	10
WC	34	1 small + 2 large flush	1	34
Total consumption, actual project				101.75

Reuse-systems for rain/grey water

If reuse-systems for rain/gray water is present, enter the expected reuse in liters/person/day

Reuse of rain/grey water	27	liters / person / day

Result to transfer manually to the Active house evaluation tool

Fixed value / National average consumption	155	Liters/ person / day
Consumption for actual project	74.75	Liters/ person / day
Saving in percentage	52	**percentage**

Figure 57 calculation from the Active House Freshwater consumption tool

Rainwater collection calculation

Apartments 53 pc

People in building p = 100

Roof area A = 1560 m^2

Rainfall in Helsinki R = 650 mm

Collected water C =A x R / 1000 = 1560 x 650 = 1 014 000 L

Water Reuse rate = C / days / p = 1 014 000 / 365 / 100 = 27.78 L/person/day

2.13 Sustainable construction

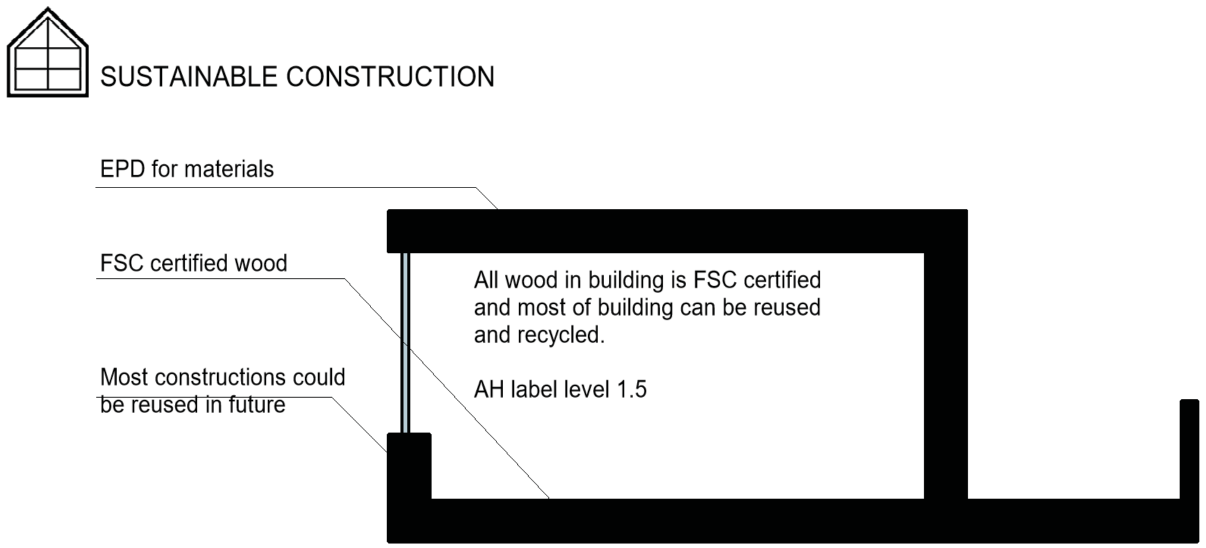


Figure 58 Sustainable construction strategy

Globally construction industry accounts for 35 % of material use, as described in chapter Built industry – biggest polluters . In close future we might see shortage of some raw materials, therefore, when designing buildings, it is important to evaluate material origin, recycled content and the possibility of material reuse at the end of building`s lifecycle.

To achieve the highest score according to Active House Radar sustainable construction criteria, at least 50 % of the building’s materials should be reusable and recyclable in end of the building`s lifecycle. All the wood used in the building should have FSC (Forest Stewardship Council) certification.

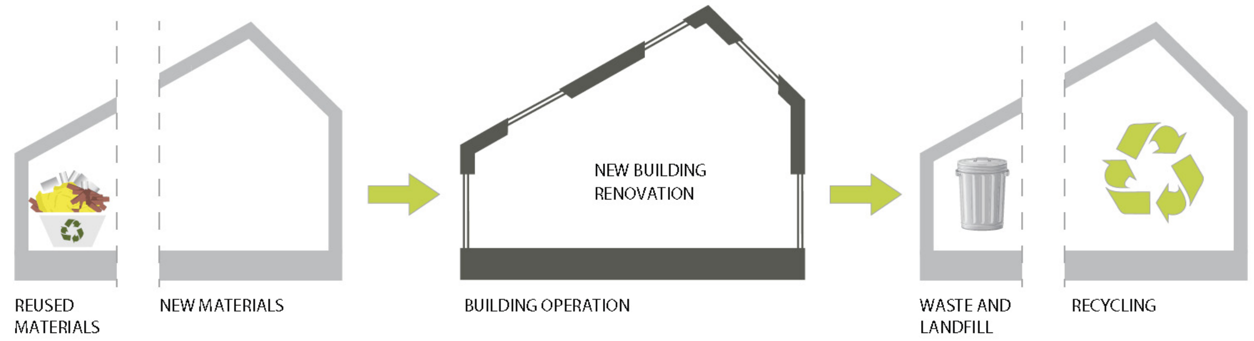


Figure 59 Active house reusable content diagram

Active House also considers how the building can be disassembled for recycling and re-use after its end of life. In the Base project, all construction was made from prefabricated concrete elements that could be recycled at the end of building`s lifecycle. But considering current typical construction methods, it is safe to assume, that in order to recycle the concrete, building will be demolished, and all elements will be broken down in small pieces to remove the reinforcement from the concrete. Metal will be used again but concrete will only be usable in road construction as a sublayer. This method reduces material value.

In the New design the buildings main structure is constructed from wood. Wooden construction, at the end of the building`s lifecycle will be a lot easier to take down and even reuse in a new project. The load bearing capacity of Cross Laminated timber (CLT) is easy to find out just by assessing element appearance, whereas concrete elements rely on metal reinforcements whose load bearing capacity is impossible to evaluate without taking the element apart. It is more precarious to reuse concrete elements without knowing the element`s bearing capacity.

Other major changes from the Base project was the choice of insulation material. Instead of mineral base insulation material that would not be possible to reuse and recycle easily, mix of hemp shives and sapropel was used. Hemp shives come from leftovers of hemp fiber production. This woody material part is mixed together with sapropel and dried to form a solid insulating material. Sapropel is a semi-renewable resource of the subterranean depths rich in organic matter - it is lime and fine-grained inland sediment. Sapropel is extracted from lakes. Sapropel extraction from lakes renews life in the lake as the oxygen levels rise in water. Benefit of the Sapropel and Hemp mix has a positive environmental impact and it is reusable. Material could be broken in parts and reused in new constructions by applying a controlled amount of water.

Benefit of the Sapropel and Hemp mix material is not only materials positive environmental impact but as well reusability. Material could, be broken in parts and reused in new construction by applying controlled amount of water.

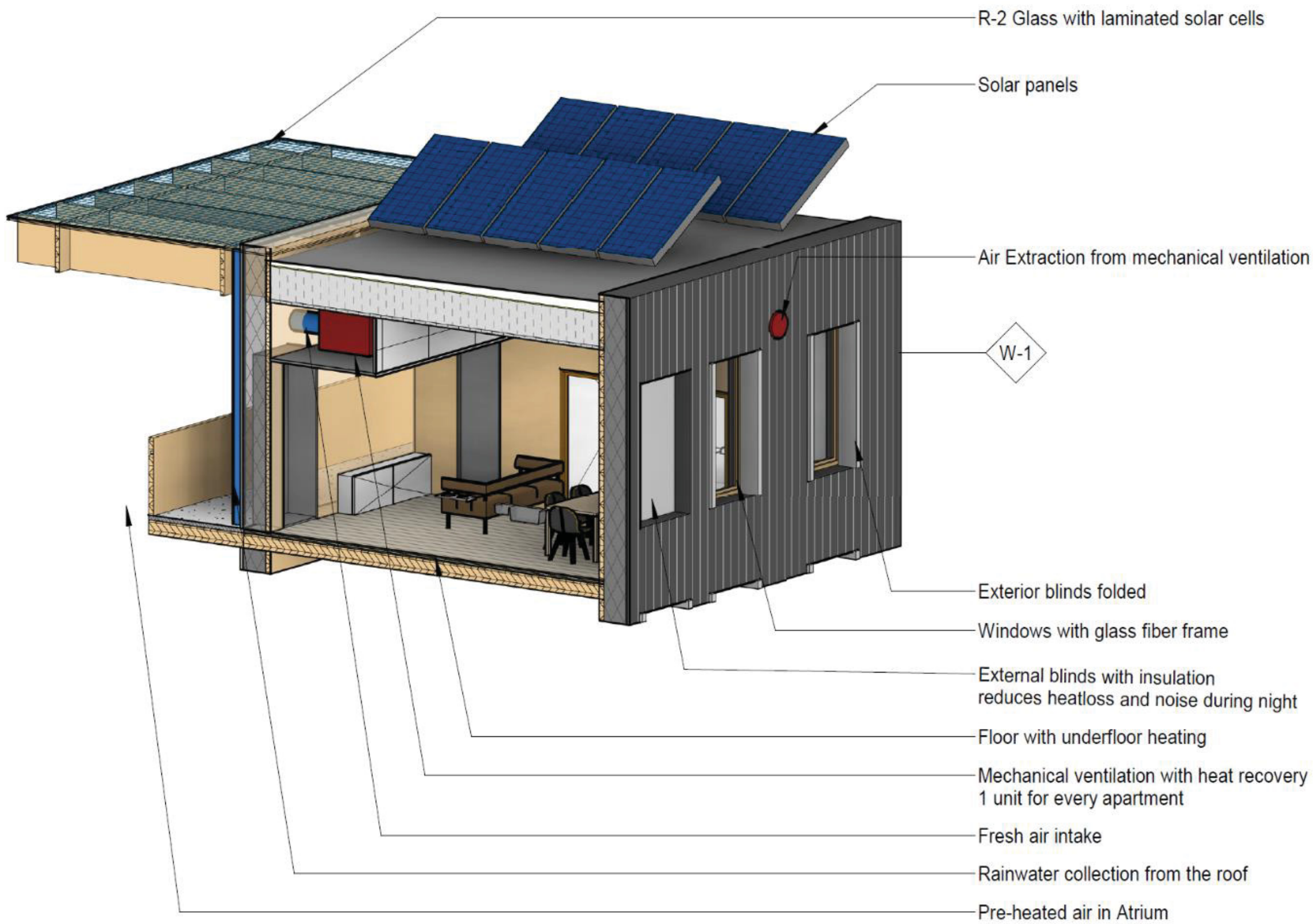
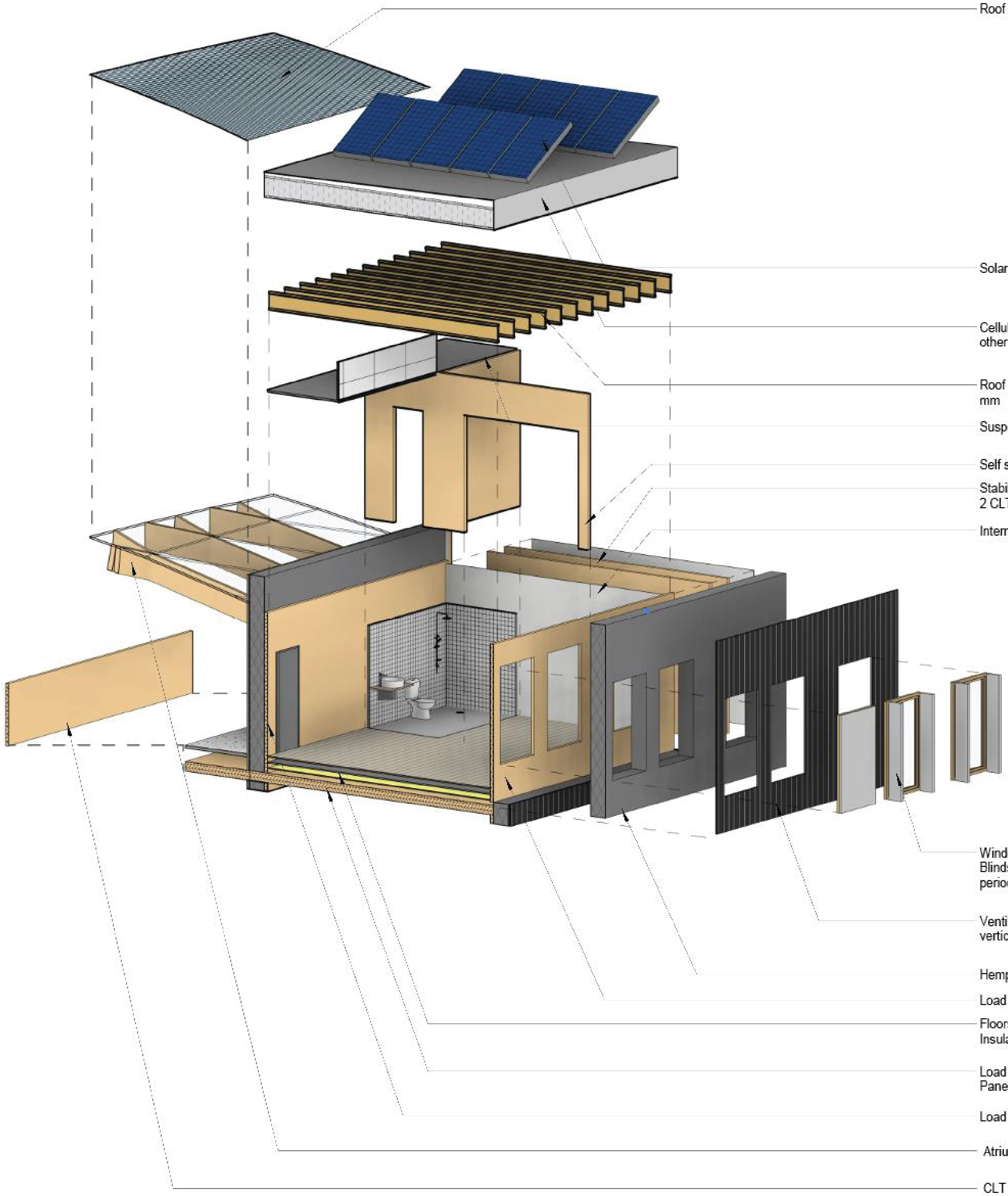


Figure 60 New projects Active house strategy

This perspective section illustrates the passive strategies integrated into building`s fabric. In the finished state, the building has a few elements that indicate its green-minded design, but overall, for the sake of sustainability, it does not compromise on the user experience. Some of the elements and strategies enhance user experience. Materials selected for construction mostly are natural and do not harm indoor air quality.



Materials used in construction are made with the possibility to reuse them in new construction.

The main construction is made from large CLT panels that could be taken apart and reused in new construction. In buildings elements

The buildings Insulation layer is monolithic mass made from Hemp shives and sapropel. If this material is broken down mixed with water and new sapropel it could be reused in new construction.

In-floor constructions, where it was possible concrete was replaced with Limecrete. More sustainable material than concrete with its lower embodied energy and properties that allow to reuse it by breaking down construction and remixing with water and lime in a new mix. Limecrete is a softer material than concrete, it would not be easy replacement in load-bearing constructions but for flooring finish, it works as good as concrete.

Other materials and equipment do not have specific reuse and recycle intend designed in the building but there is always the possibility to reuse glass in windows. Other materials and equipment count for a small portion of building`s total weight therefore reusability of them give a small impact on the overall score.

2.14 Data from Active house project

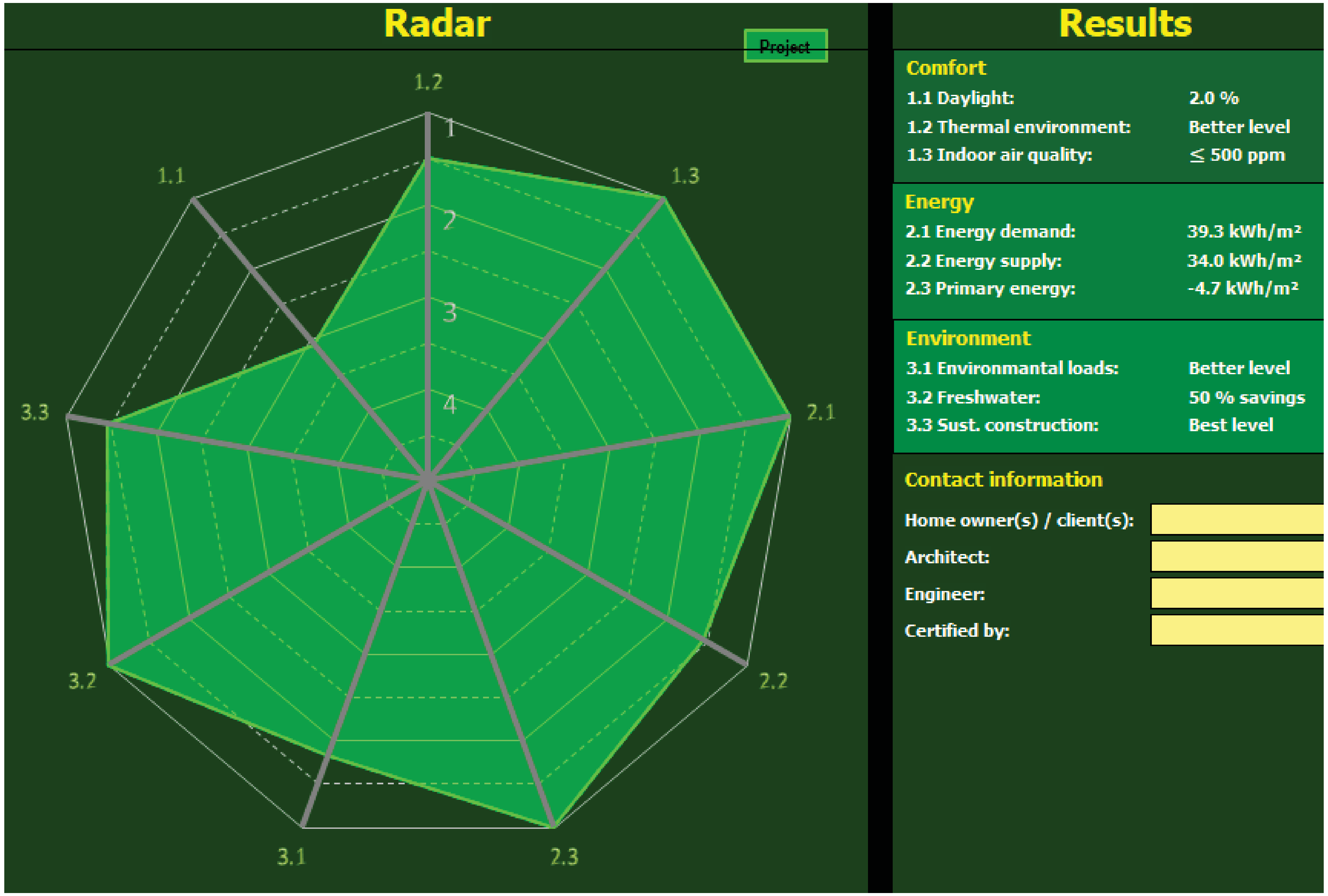


Figure 61 Active House Radar for the new design

Active House radar chart

This chart illustrates the calculated overall performance of the new Building. I believe that the goal of this project has been met and the new design represents a building that is designed using active house principles and meets the highest criteria.

The new building has achieved the lowest result in the Daylight factor criterion. Considering that this is a multistorey building that does not provide a possibility to design skylights in all apartments, I conclude that the achieved results in the Daylight factor are good considering the circumstances. As already mentioned in chapter 2.6 Daylighting, the importance of all rooms in the building meeting these criteria is debatable.

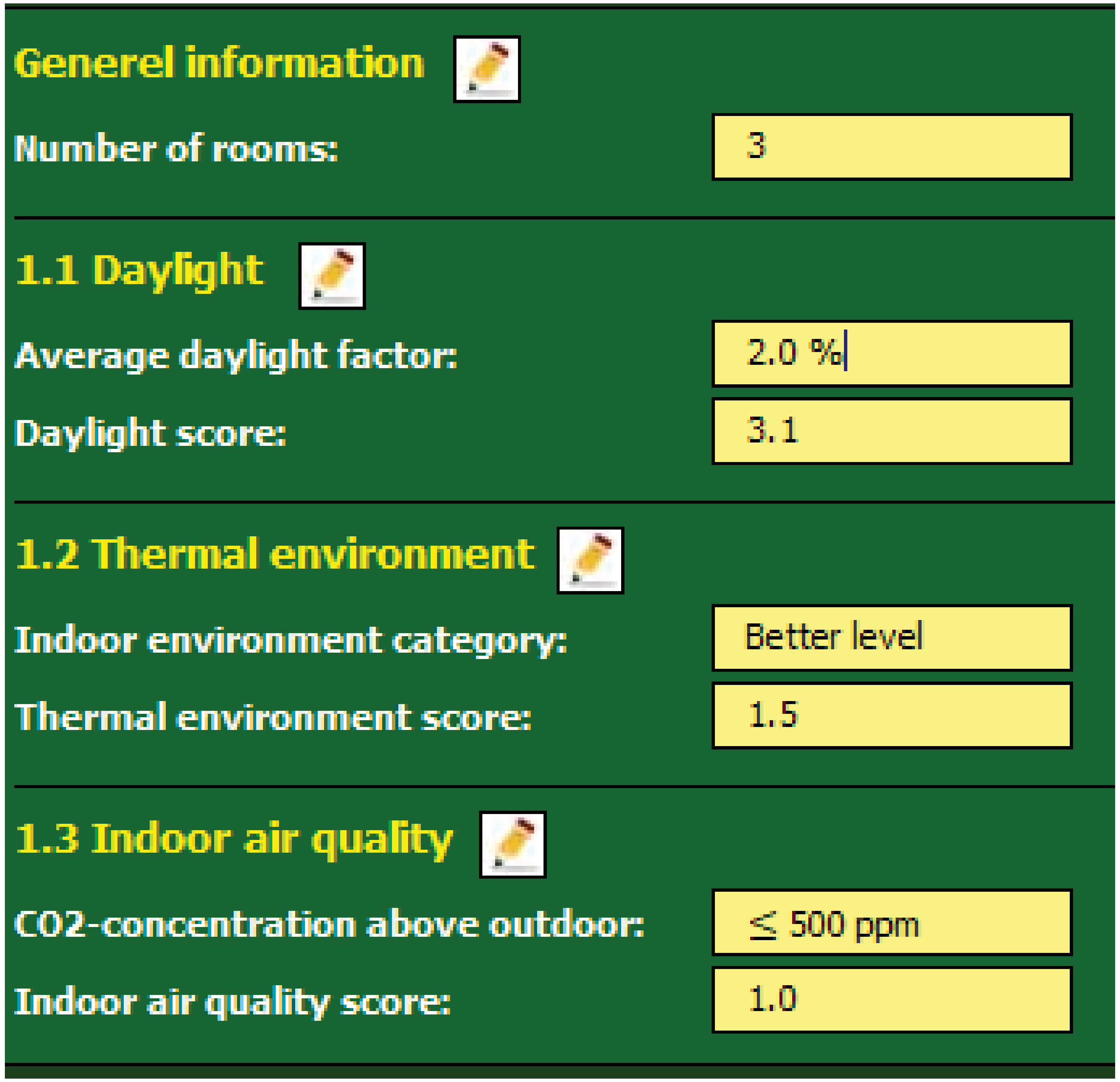


Figure 62 Comfort results for the new design of Active house, made with the Active House tool.

The Daylight analysis was done for the apartment with the weakest score, as the Active house tool does not allow to enter more than 20 rooms. The simulations and analysis explained in chapter 2.6 Daylight were done in such a way that the building would achieve the Daylight factor of at least 2,5 % that would give an overall score of 2.5 or more. When the final simulations, that include the window blinds and the surrounding environment, were finished, there were a few areas that had slightly lower scores. The apartment with the lowest score was used for calculating the Daylight results. The apartments in the higher floors have better scores, as shading from the surrounding buildings is an important factor for the calculations.

The thermal environment is a very subjective value. The temperature that one person might find comfortable, others might find too hot or too cold. The floor heating system in all apartments provides the possibility to control the indoor temperature. Every room has a thermostat. The selected interior materials - wood flooring and interior wall finish, give the inhabitants a warmer feeling during the winter. The exterior wall construction has a considerable thermal storage capacity that provides and ensures a stable temperature of the construction. The exterior blinds and cross ventilation prevent the apartments from overheating during the summer months. The exterior blinds would automatically close during the daytime when the apartment unoccupied. And during the nighttime windows could open and cool down the construction.

Every apartment in the project has its ventilation unit that provides not only a demand-driven fresh air supply for a specific room but as well a possibility for saving energy because the ventilation could be switched off during the unoccupied hours.

Energy		
General information		
Treated floor area:	3500.0	m2
2.1 Energy demand		
Space heating:	18.3	kWh/m2
Domestic hot water:	10.0	kWh/m2
Mechanical ventilation:	5.0	kWh/m2
Cooling:	0.0	kWh/m2
Control systems:	2.0	kWh/m2
Lighting:	4.0	kWh/m2
Total:	39.3	kWh/m2
Energy demand score:	1.0	
2.2 Energy supply		
Electricity produced by renewable energy:	34.0	kWh/m2
Heat produced by renewable energy:	0.0	kWh/m2
Total:	34.0	kWh/m2
Percentage of renewable energy supply:	86.5	%
Energy supply score:	1.5	
2.3 Primary energy performance		
Total:	-4.7	kWh/m2
Primary energy performance score:	1.0	

Figure 63 Energy results for the new design of Active house, made with the Active House tool.

In the Base project, most of the energy demand is used for space heating (more than 70). To ensure a low energy demand in the Active house project, a demand for space heating needed to be addressed. The energy applied for space heating levels out with the energy lost through the envelope. Looking back on the energy calculations in the Base project, it was clear that the most significant energy loss comes from windows and ventilation. In addition to making an airtight, well-insulated envelope, new strategies were introduced.

Insulated exterior window blinds would provide a significant energy reduction. While the blinds would be closed, they would provide lower U-value for the windows, stop the light pollution indoors during the night, reduce street noise indoors, and stop the heat gain during the day in summer. The window blinds would operate automatically, closing windows during the daytime, when the space is unoccupied, and during nighttime when the inhabitants are sleeping, in total accounting for more than 50 % of the time.

Each apartment has a mechanical ventilation unit with heat recovery. The amount of air change in the rooms is dynamically changed depending on the number of occupants. It will not only lower the energy costs but increase the fresh air quality.

The semi-heated atrium functions as a thermal buffer zone. It reduces the temperature difference between the two sides of the outside wall. To avoid overheating during the summer, the roof glazing of the atrium has integrated solar panels for shading and energy production.

The roof of The Active house project is covered with solar panels to maximize energy production. Even though the building is achieving a high Active house score, it is not clear how the energy production would be managed in this project. Typically, every apartment would make an individual electricity contract. Considering that the building has solar panels that could support 86 % of energy demand, it would be reasonable to use this energy in public functions. The rest of the energy could be split between the apartments, but it would depend on the conditions of the contracts, communication between the inhabitants and energy providers. Overall, the energy distribution in the building is a problematic point for this system.

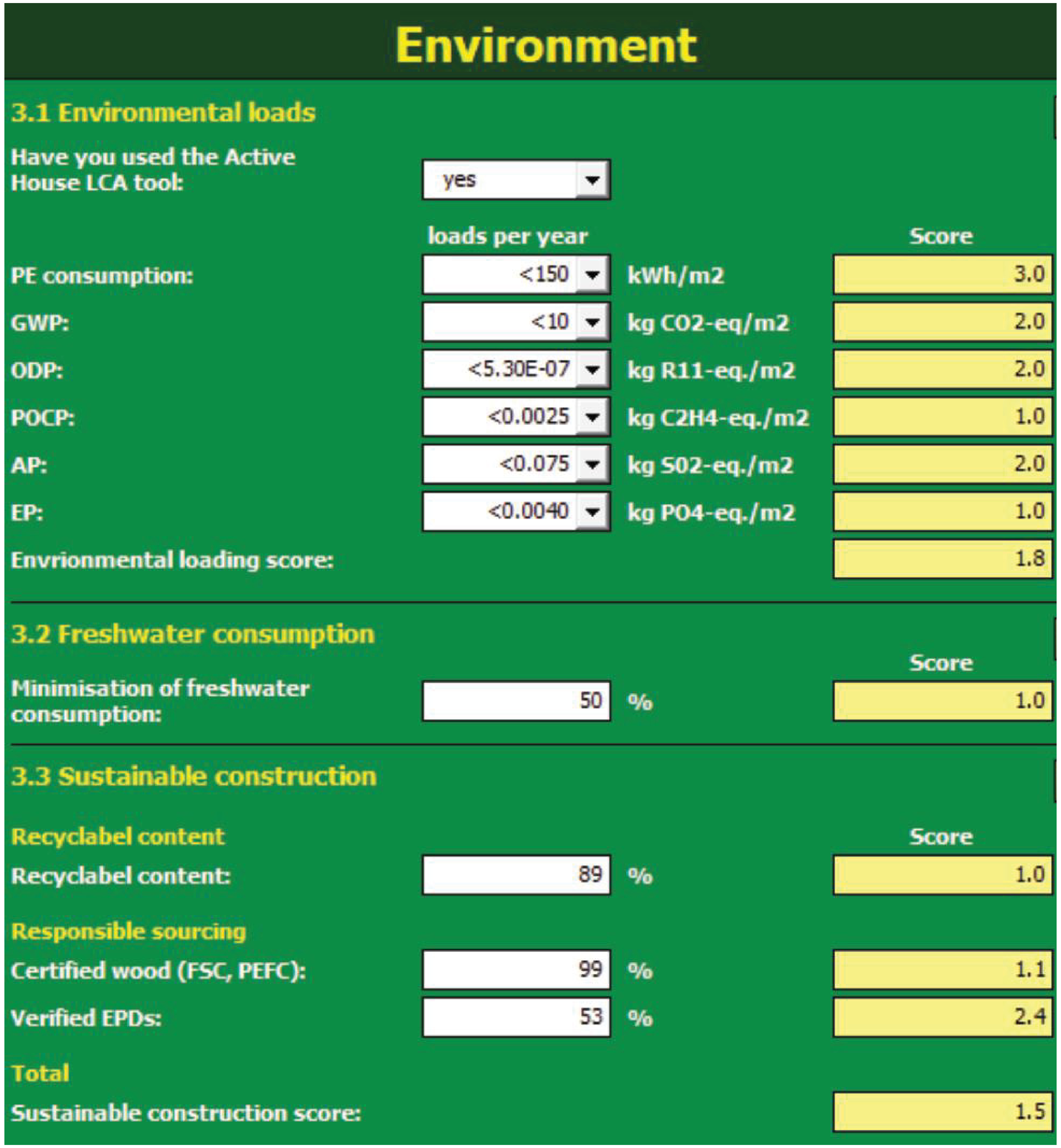


Figure 64 Environment results for the new design of Active house, made with the Active House tool

The Environmental loads' category analyzes the impact of typical materials on the environment during the lifecycle of the materials. A big part of the impact of the materials comes from the transportation and production of the materials. It is recommended to use local materials and avoid oil-based materials.

The materials used in the construction are environmentally friendly. The cross-laminated timber is produced locally and FSC certified. The monolithic insulation is a partly local product, the hemp shives most likely would be imported but sapropel is a natural local resource.

Freshwater consumption is reduced by use and collection of rainwater, installation of modern appliances, and shared laundry facilities with industrial style washing machines. Rainwater is collected from all roof surfaces and directed down to the basement where it is filtered and pumped to apartments and the fish tank in Atrium. Water from the fish tank is regularly circulated in the aquaponic garden. Aquaponic style planting consumes up to 90 % less water than soil-based one.

All wood material is required to have an FSC certificate. Other materials used in construction are required to make an environmental product declaration (EPD).

The percentage of a material having EPD is calculated on its weight, therefore uncertified concrete basement construction leaves a big impact on the overall result.

2.15 Drawings of the multistory building designed with Active House principles.

Figure 65 Street view to the New design of the Active House

Figure 66 View on the New design of the Active House from the building across the street

Figure 67 Building`s set-back from the property line with greenery and trees (between sidewalk and the building) provides more privacy for residents and improve the streetscape. Building`s set-back reduces the 1st floor apartment shading from the neighboring properties.

Figure 68 North Facade in the evening

Figure 69 View from the public terrace on the 4th floor

Figure 70 Public space in the Atrium is used for social gatherings, work and leisure.

Figure 71 View in the 1 room apartment.

Figure 72 4 room apartment's Livingroom

Figure 73 Hydroponic garden with a water tank in the building`s Atrium. The rainwater is used for plant watering after cleansing.

Figure 74 Playground for kinds and work meeting spaces in the building`s Atrium.

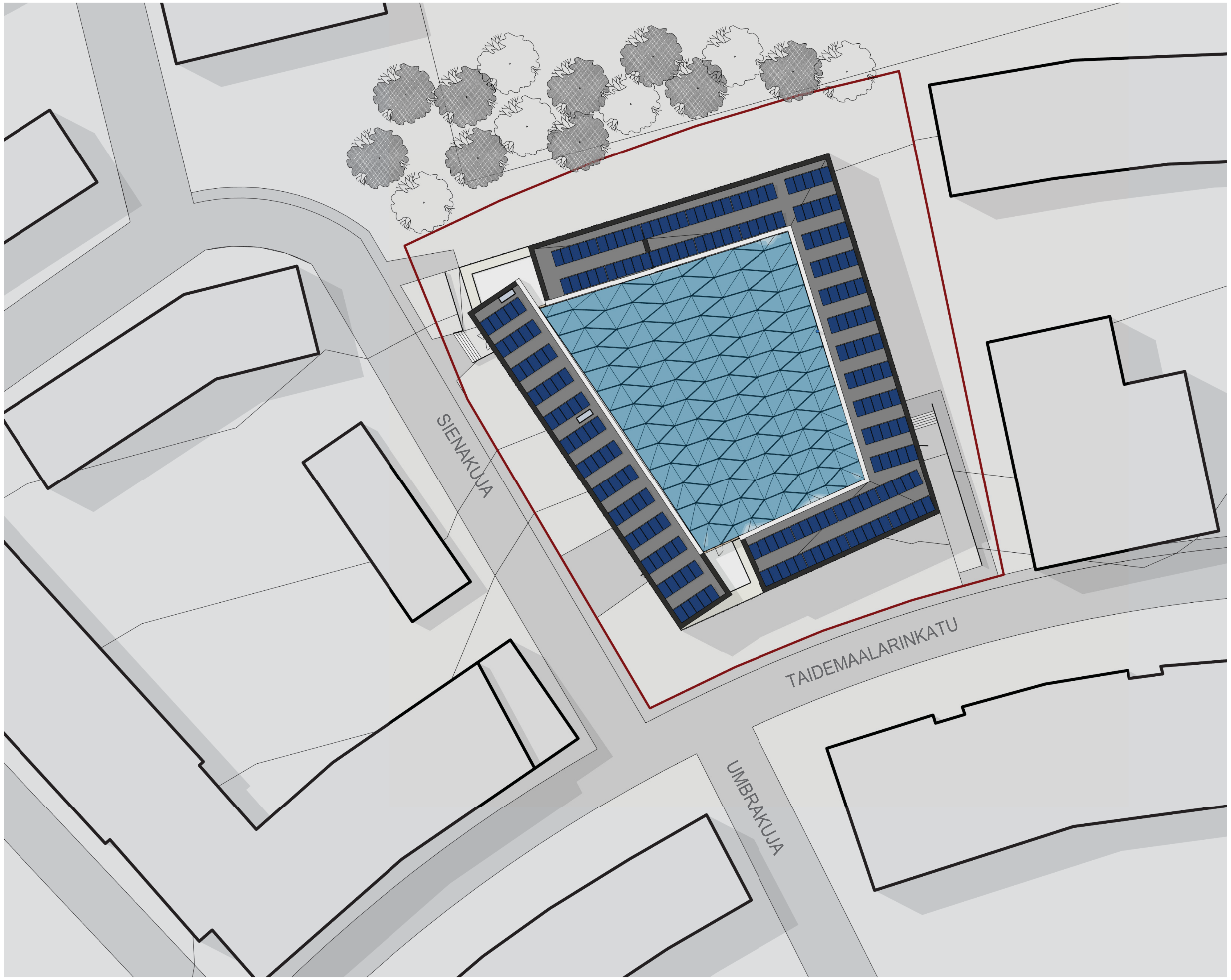
Figure 75 Evening view in the Atrium. Atrium's glass roof with solar cells generate electricity and provide shading preventing overheating.

Figure 76 Vegetation in the Atrium not only bring the nature elements in public space but also provide a space with shading, lowering temperature. Plats in the Atrium provide additional oxygen and food supply.

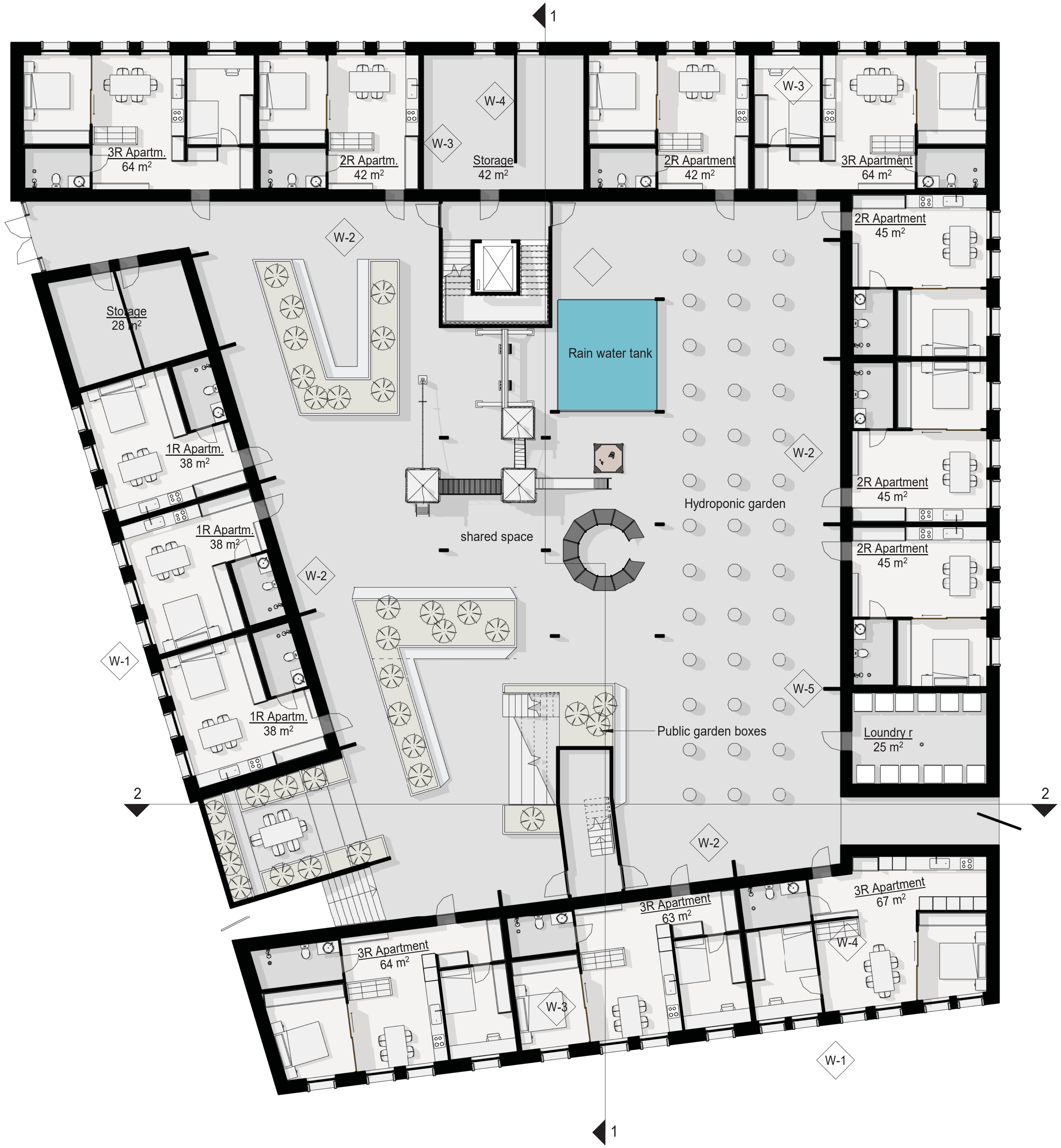
Figure 77 View of the Atrium from the 4th floor.

Figure 78 View on the new building from sidewalk.

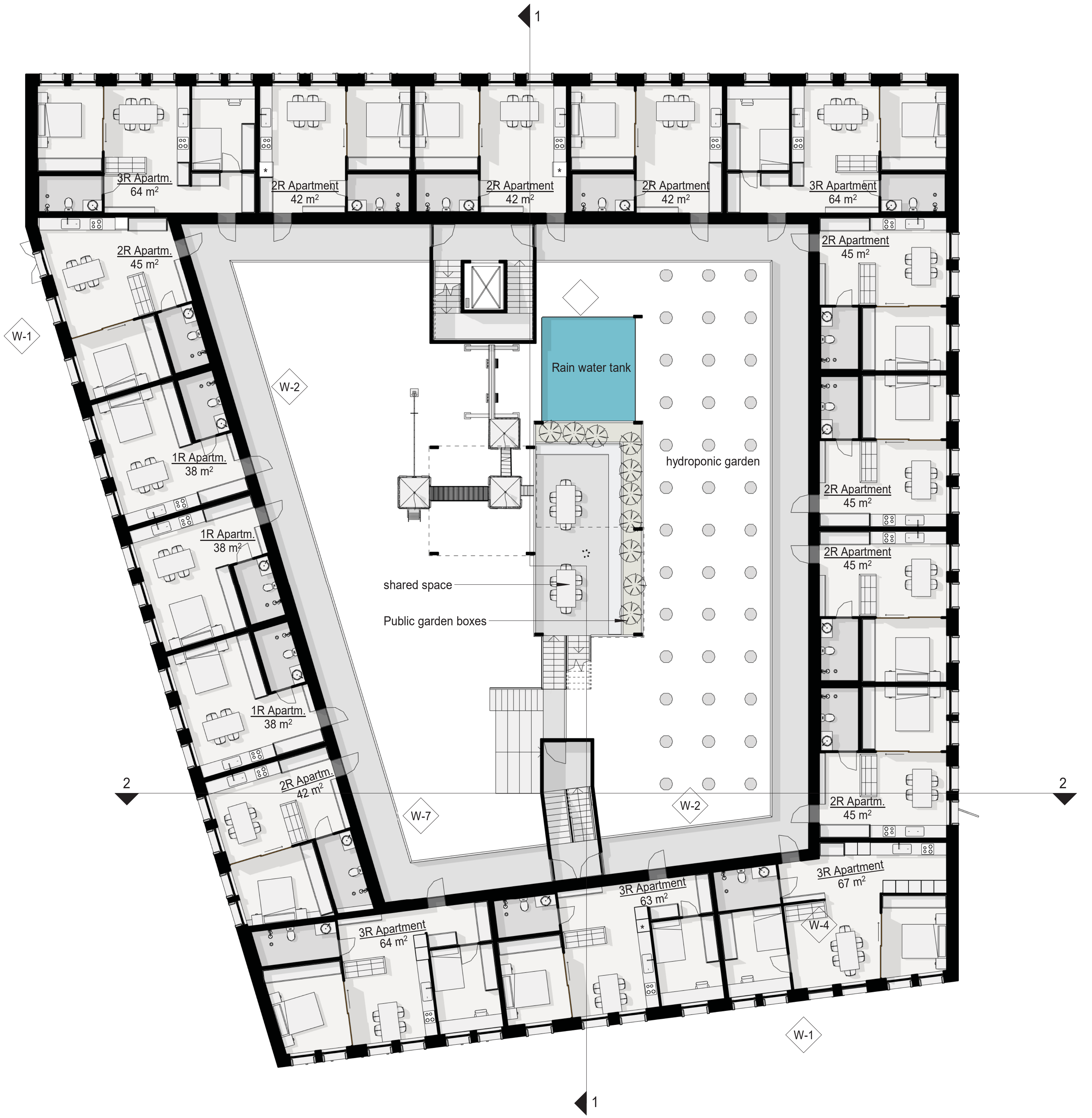
SITE PLAN
1 : 500



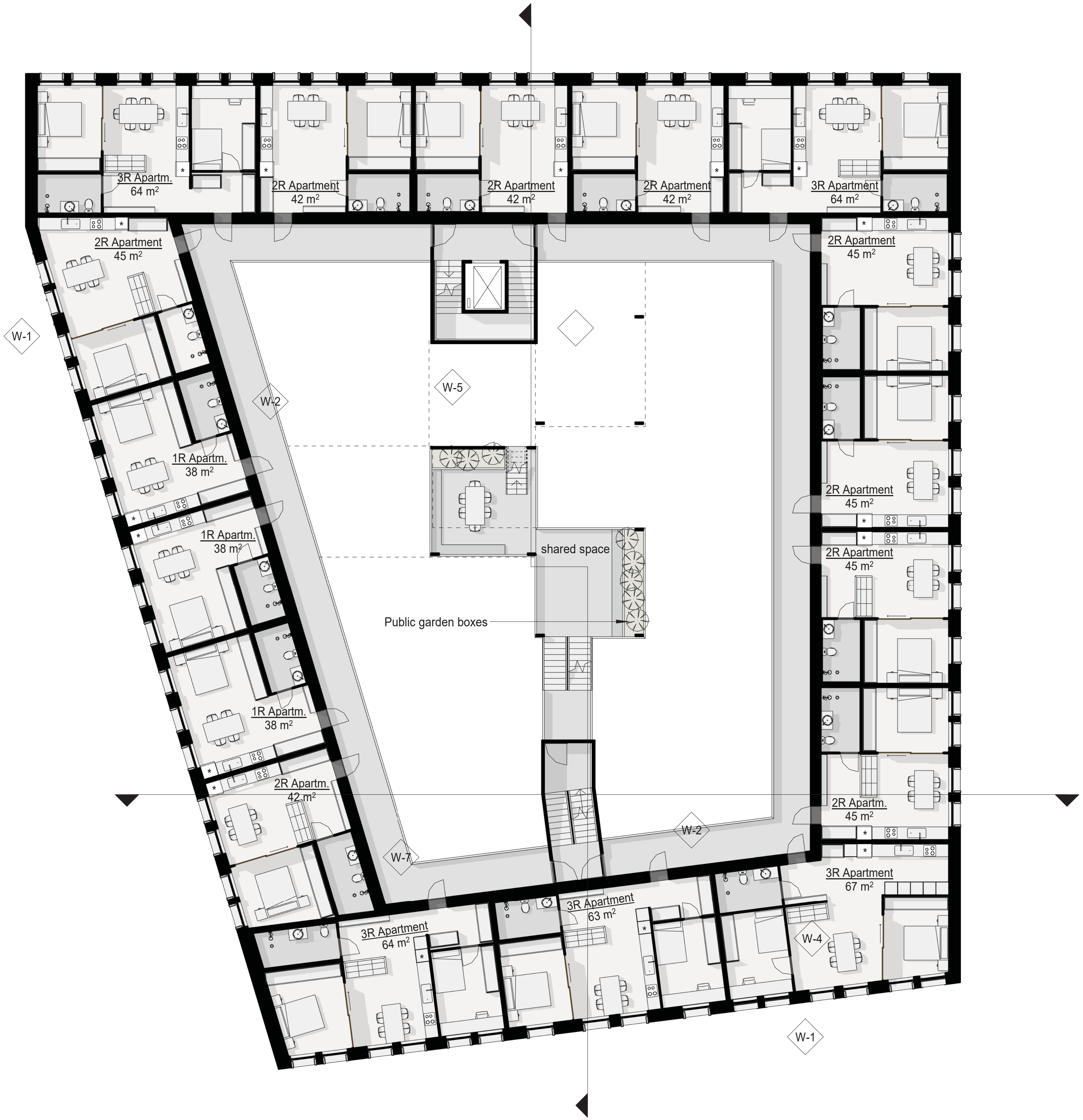
01 LEVEL
1 : 200



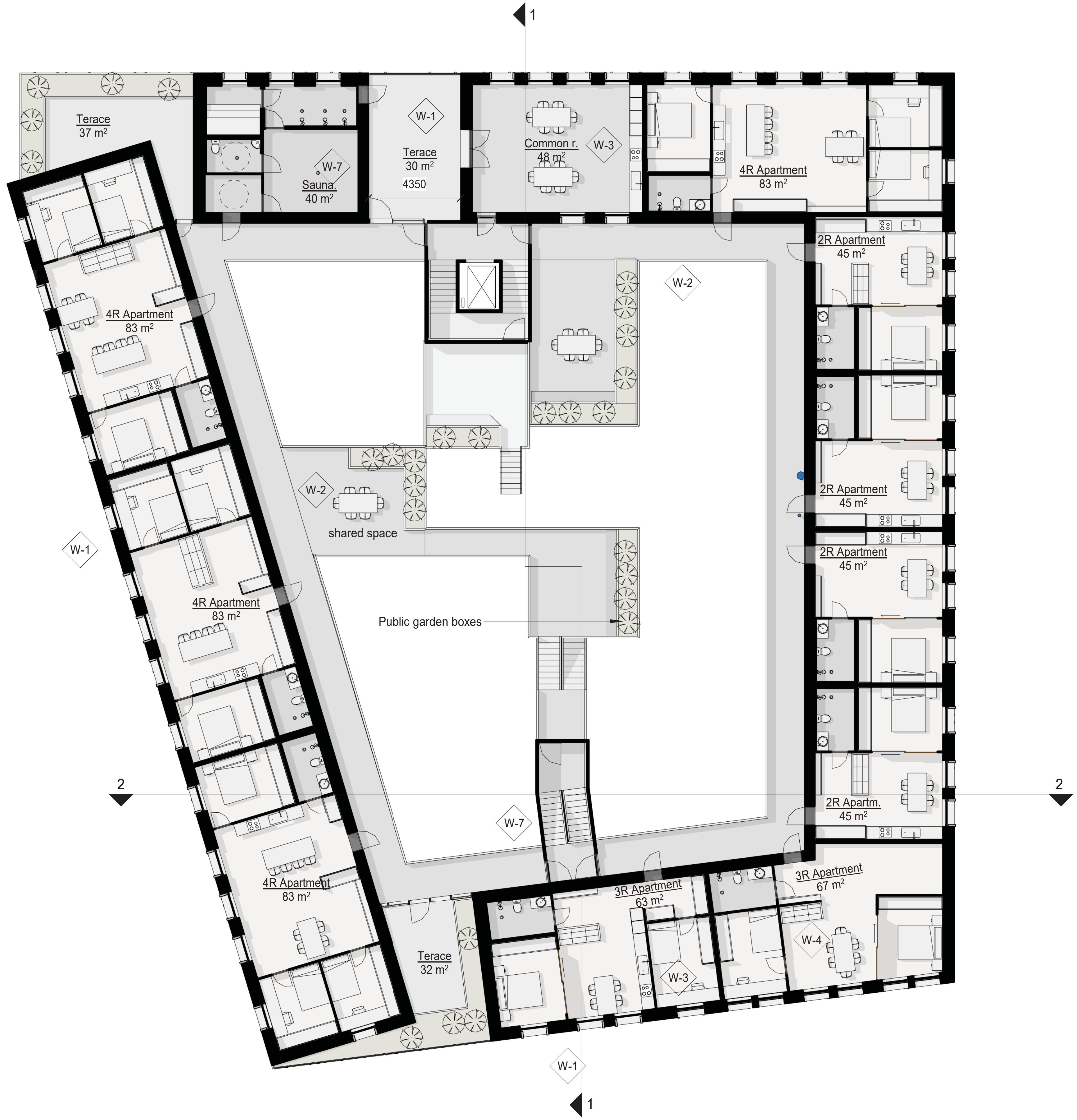
02 LEVEL
1 : 200



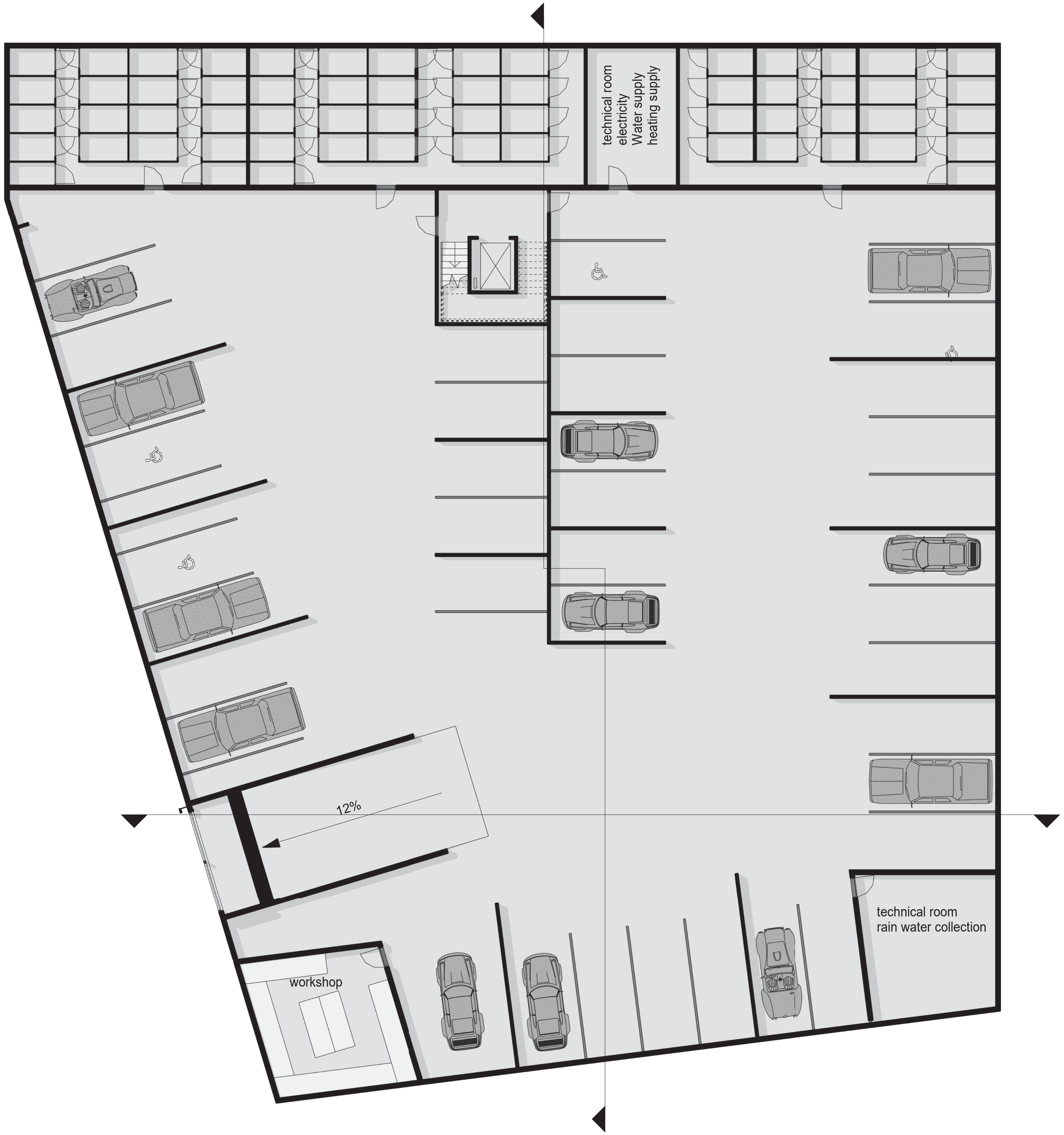
03 LEVEL
1 : 200



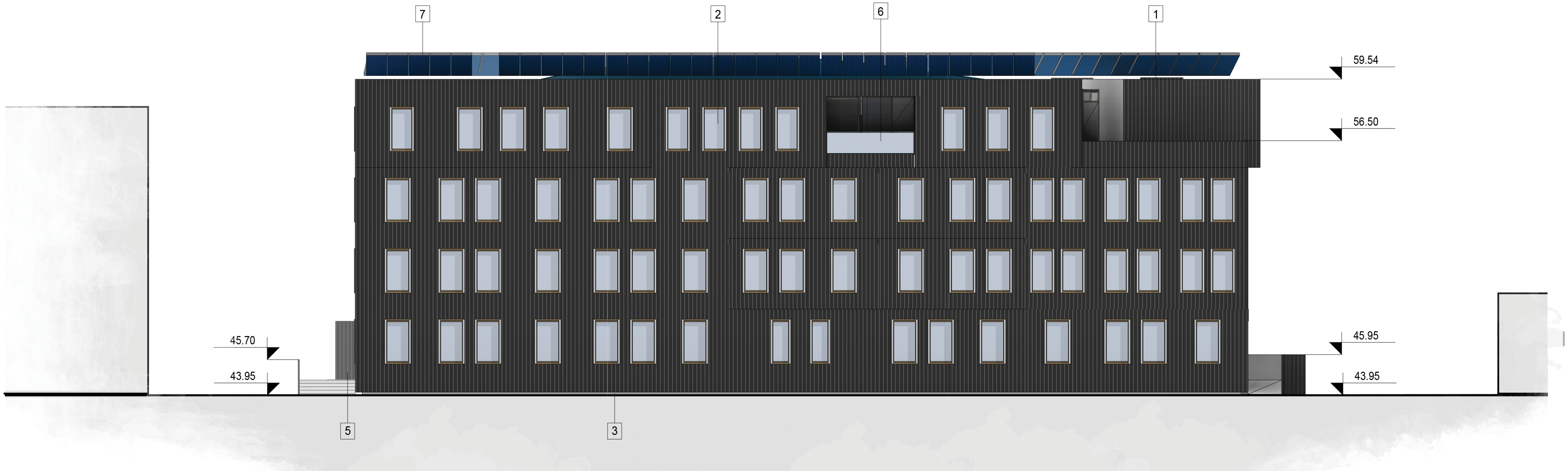
04 LEVEL
1 : 200



-01 LEVEL
1 : 200



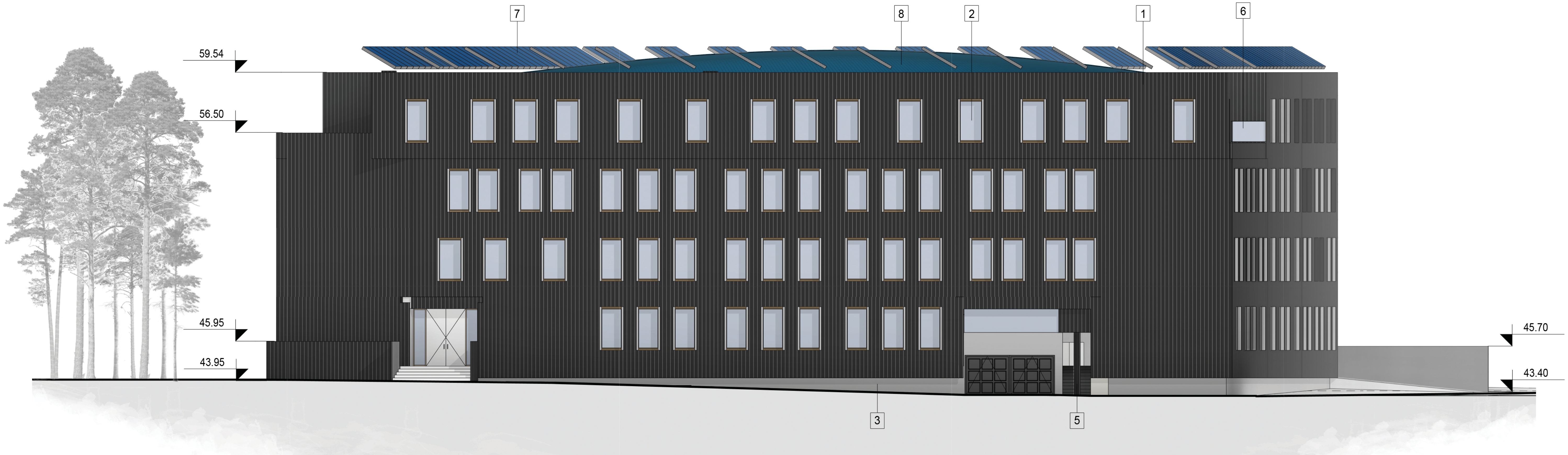
Elevation NORTH
1 : 200



MATERIALS

No	Material
1	Vertical wooden facade finish 100 mm wide,Thermally treated
2	Triple glazed windows in Wooden frames
3	Concrete panel
4	Insulated wooden blinds visually matching with facade
5	Rotating doors visually matching with facade
6	Triplex - Glass railing
7	Solar panels
8	Glass roof above atrium with integrated solar cells

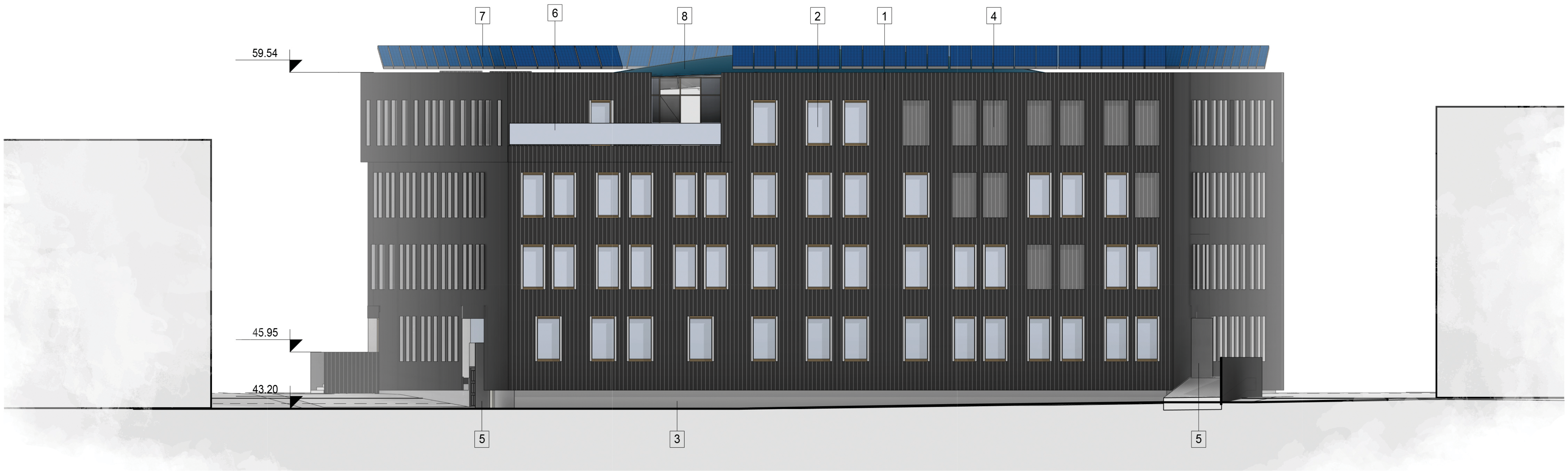
Elevation WEST
1 : 200



MATERIALS

No	Material
1	Vertical wooden facade finish 100 mm wide,Thermally treated
2	Triple glazed windows in Wooden frames
3	Concrete panel
4	Insulated wooden blinds visually matching with facade
5	Rotating doors visually matching with facade
6	Triplex - Glass railing
7	Solar panels
8	Glass roof above atrium with integrated solar cells

Elevation SOUTH
1 : 200



MATERIALS

No	Material
1	Vertical wooden facade finish 100 mm wide,Thermally treated
2	Triple glazed windows in Wooden frames
3	Concrete panel
4	Insulated wooden blinds visually matching with facade
5	Rotating doors visually matching with facade
6	Triplex - Glass railing
7	Solar panels
8	Glass roof above atrium with integrated solar cells

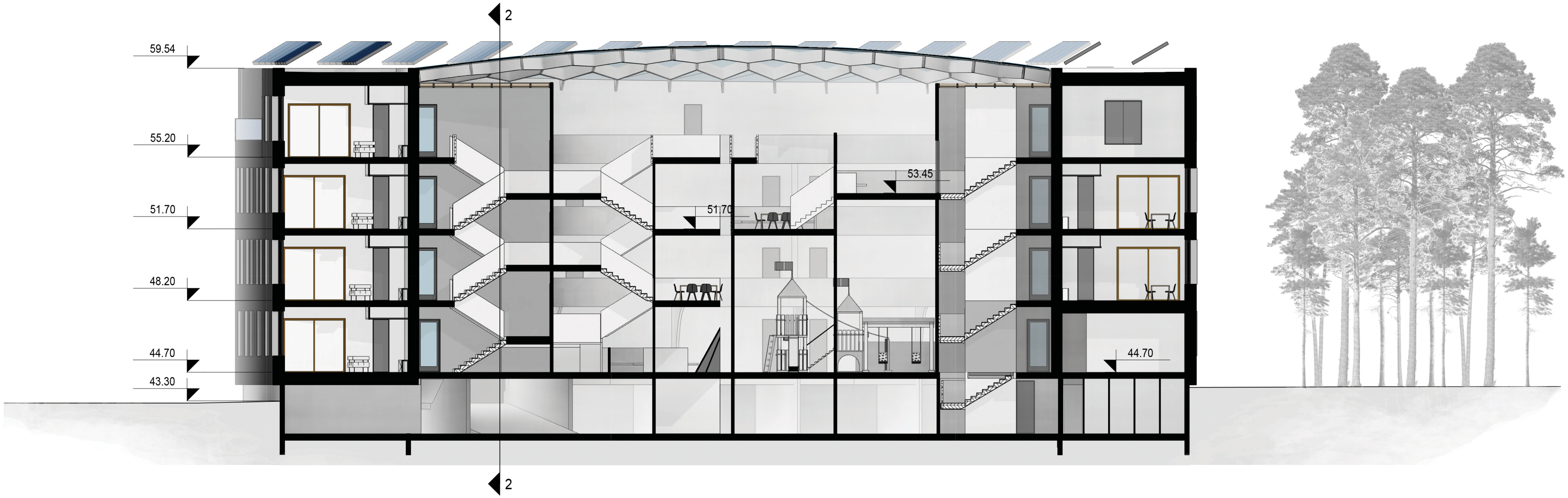
Elevation EAST
1 : 200

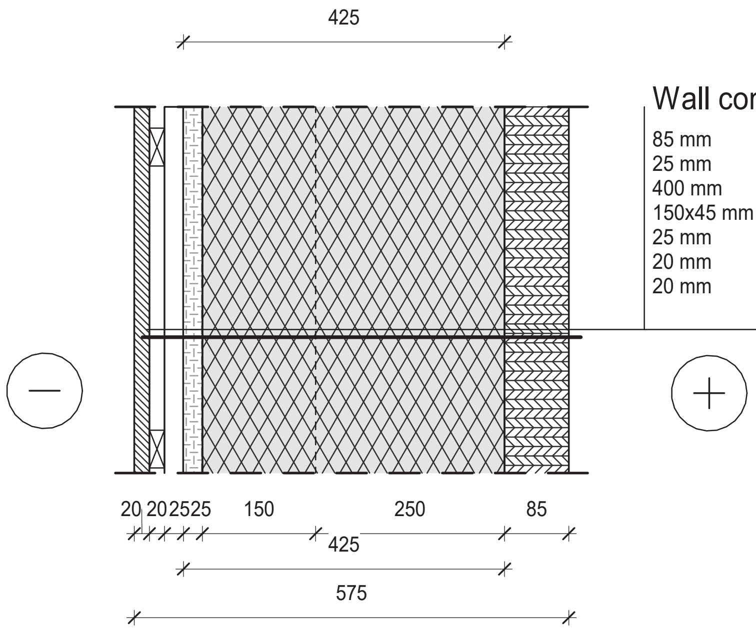
MATERIALS

No	Material
1	Vertical wooden facade finish 100 mm wide,Thermally treated
2	Triple glazed windows in Wooden frames
3	Concrete panel
4	Insulated wooden blinds visually matching with facade
5	Rotating doors visually matching with facade
6	Triplex - Glass railing
7	Solar panels
8	Glass roof above atrium with integrated solar cells

Section 2-2
1 : 200

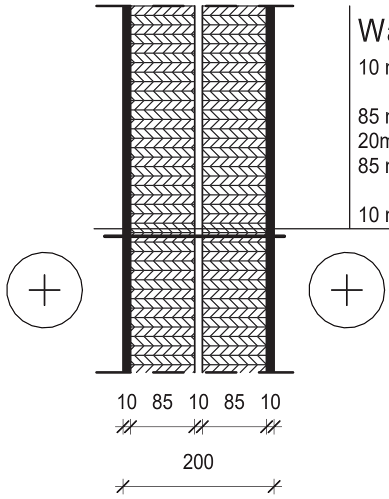
Section 1-1
1 : 200





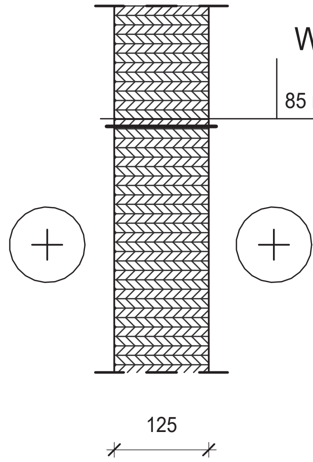
Wall construction W-1

85 mm	Dowel Laminated timber
25 mm	Wood fiberboard
400 mm	Hemp sapropel wall construction with
150x45 mm	framing
25 mm	Distance battens
20 mm	Battens
20 mm	Wooden Facade wall covering (Thermaly treated)



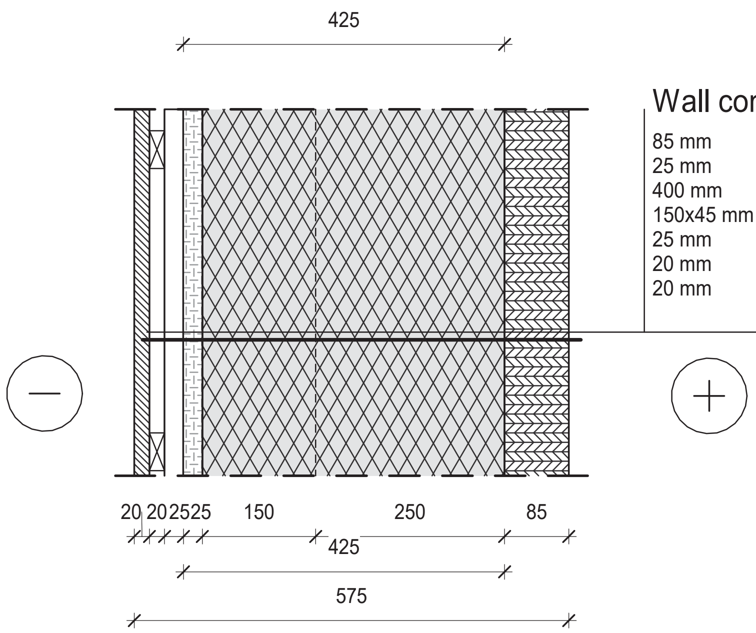
Wall construction W-3

10 mm	Clay plaster
	Wood mesh
85 mm	CLT wall element
20mm	air gap
85 mm	CLT element
	Wood mesh
10 mm	Clay plaster



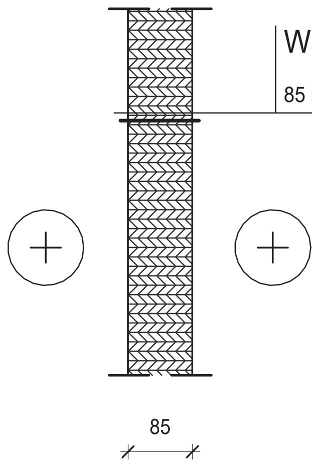
Wall construction W-5

85 mm	CLT wall element



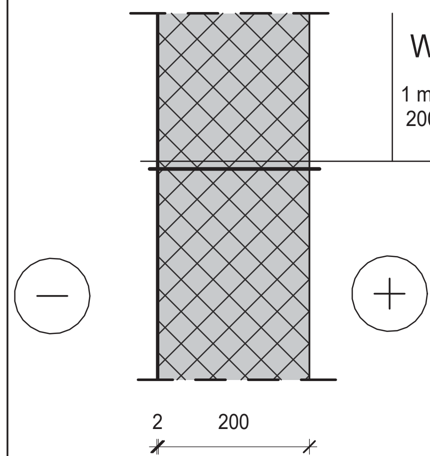
Wall construction W-1

85 mm	Dowel Laminated timber
25 mm	Wood fiberboard
400 mm	Hemp sapropel wall construction with
150x45 mm	framing
25 mm	Distance battens
20 mm	Battens
20 mm	Wooden Facade wall covering (linen oil finish)



Wall construction W-4

85 mm	CLT wall element

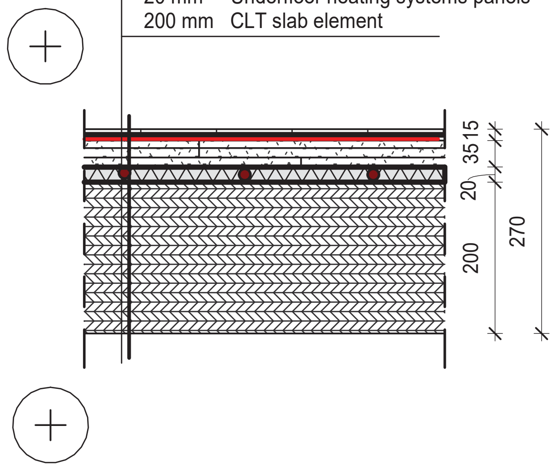


Wall construction W-6`

1 mm	1K waterproofing layer
200 mm	Reinforced concrete elements

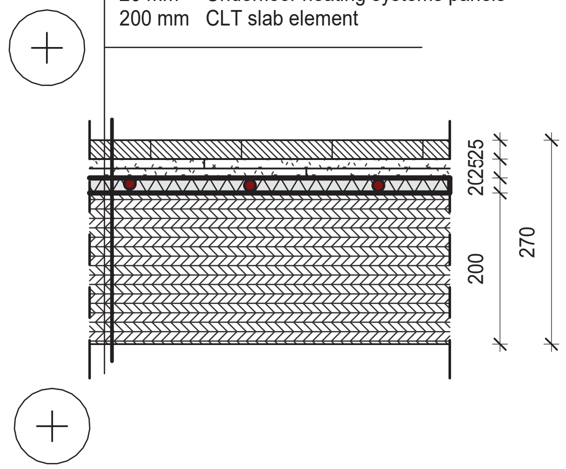
Floor constructions F-2

9 mm	Ceramic Tiles
5 mm	Tididile glue
1 mm	Waterproofing layer k1
10 mm	Fermacell board
25 mm	Fermacell flooring element (2 E 22)
	Heat conducting plate
15 mm	Pex-a pipe heatinng system
20 mm	Underfloor heating systems panels
200 mm	CLT slab element



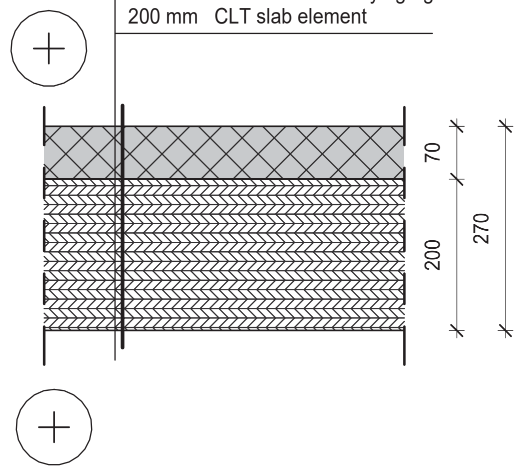
Floor constructions F-3

25 mm	wood flooring
25 mm	Fermacell flooring element (2 E 22)
	Heat conducting plate
15 mm	Pex-a pipe heatinng system
20 mm	Underfloor heating systems panels
200 mm	CLT slab element



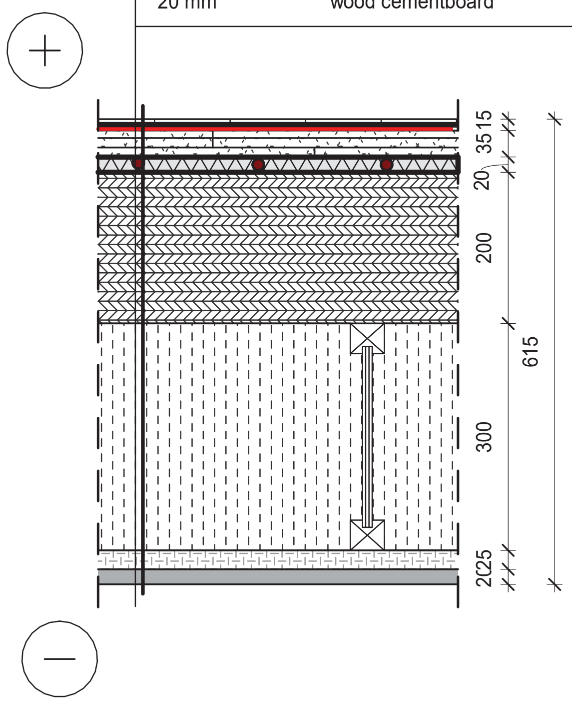
Floor constructions F-4

1 mm	Linen oil finishing coat
70 mm	Limecrete with clay agregade
200 mm	CLT slab element



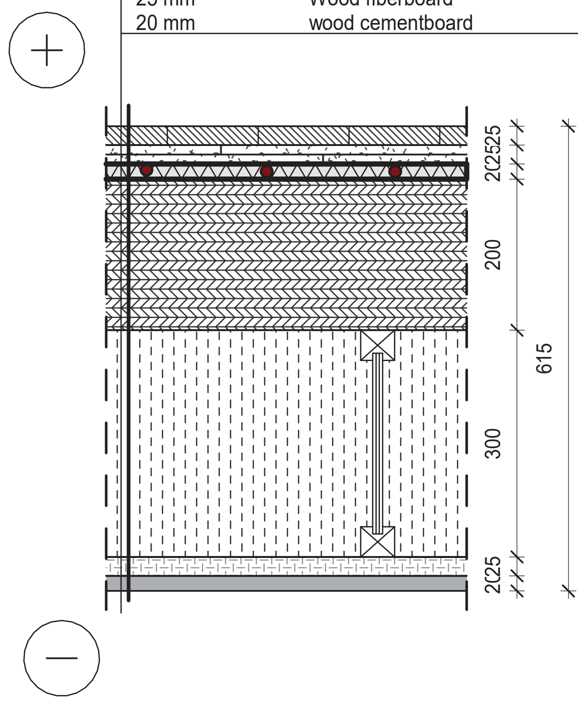
Floor constructions F-5

9 mm	Ceramic Tiles
5 mm	Tididile glue
1 mm	Waterproofing layer k1
10 mm	Fermacell board
25 mm	Fermacell flooring element (2 E 22)
	Heat conducting plate
15 mm	Pex-a pipe heatinng system
20 mm	Underfloor heating systems panels
200 mm	CLT slab element
300 mm	Celulose insulation with I-joists
25 mm	Wood fiberboard
20 mm	wood cementboard



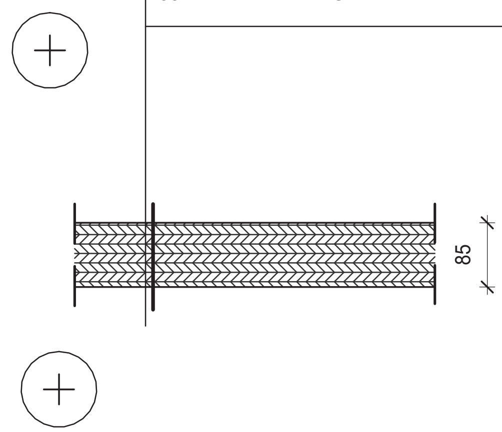
Floor constructions F-6

25 mm	wood flooring
25 mm	Fermacell flooring element (2 E 22)
	Heat conducting plate
15 mm	Pex-a pipe heatinng system
20 mm	Underfloor heating systems panels
200 mm	CLT slab element
300 mm	Celulose insulation with I-joists
25 mm	Wood fiberboard
20 mm	wood cementboard



Floor constructions F-7

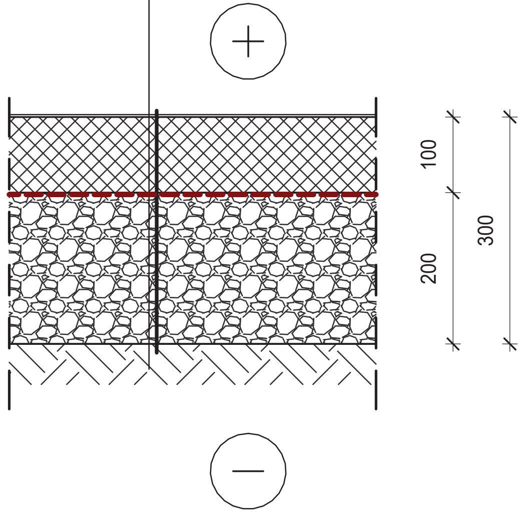
	Linnen oil treatment
85 mm	CLT slab element



Floor constructions F-1

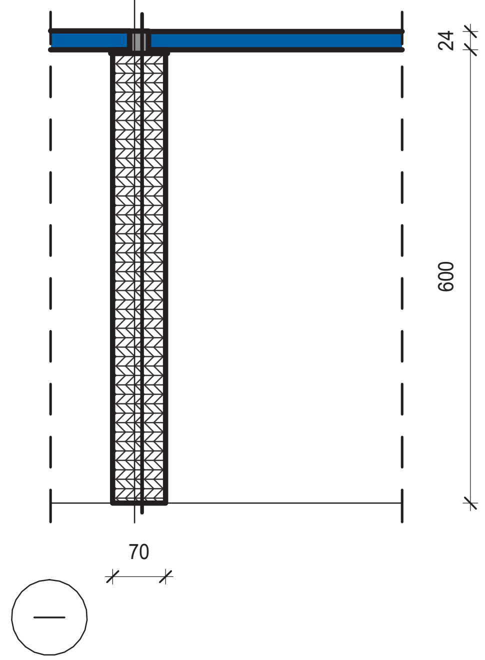
basement

	Linen oil finishing coat
100 mm	Concrete slab with glass fiber reinforcement
8 mm	glassfiber reinforcement 300x300 mm
	Geo terxtile
200 mm	Gravel
	Pressed soil



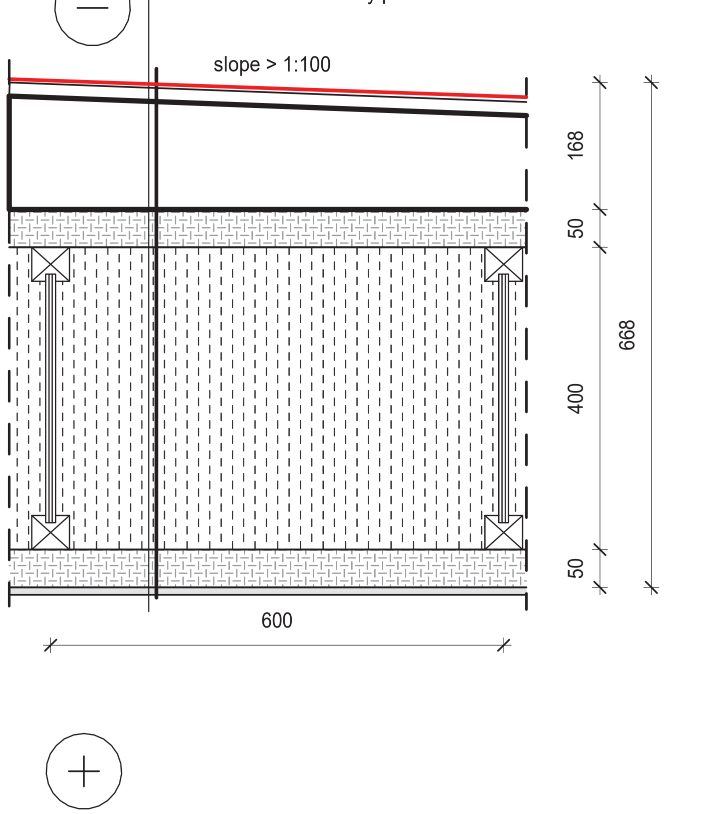
Roof constructions R-2

	Lamination
	Solar cells 70 % coverage
24 mm	Safety glass triplex
700x70 mm	CLT frame



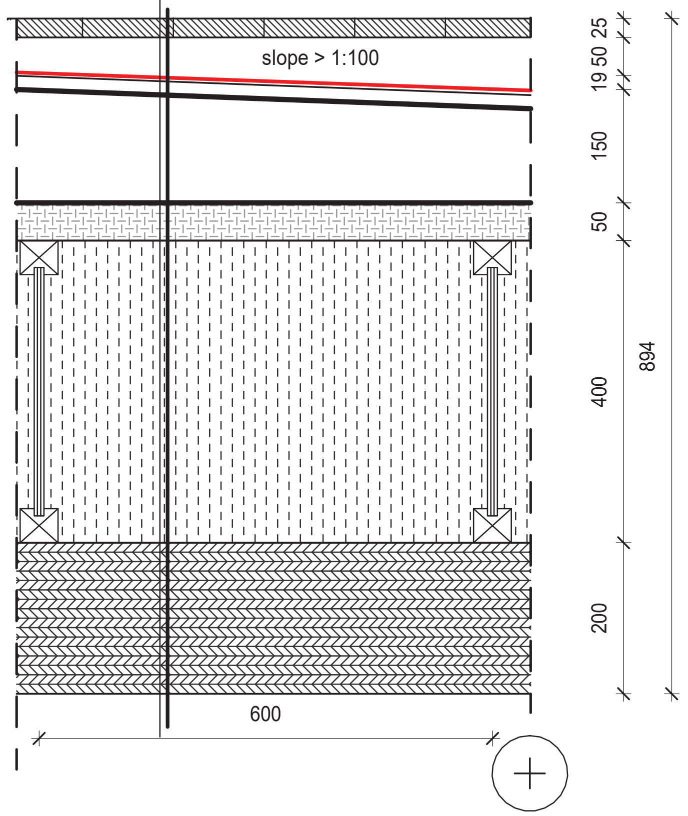
Roof constructions R-1

1 mm	Waterproof membrane Derbipure
18 mm	Plywood
150>50 mm	Ventilated cavety with wooden battens
50 mm	Woodfiber board
400 mm	I-joists c-c 600 mm with Celulose insulation
50 mm	Woodfiber board
10 mm	Clay plaster

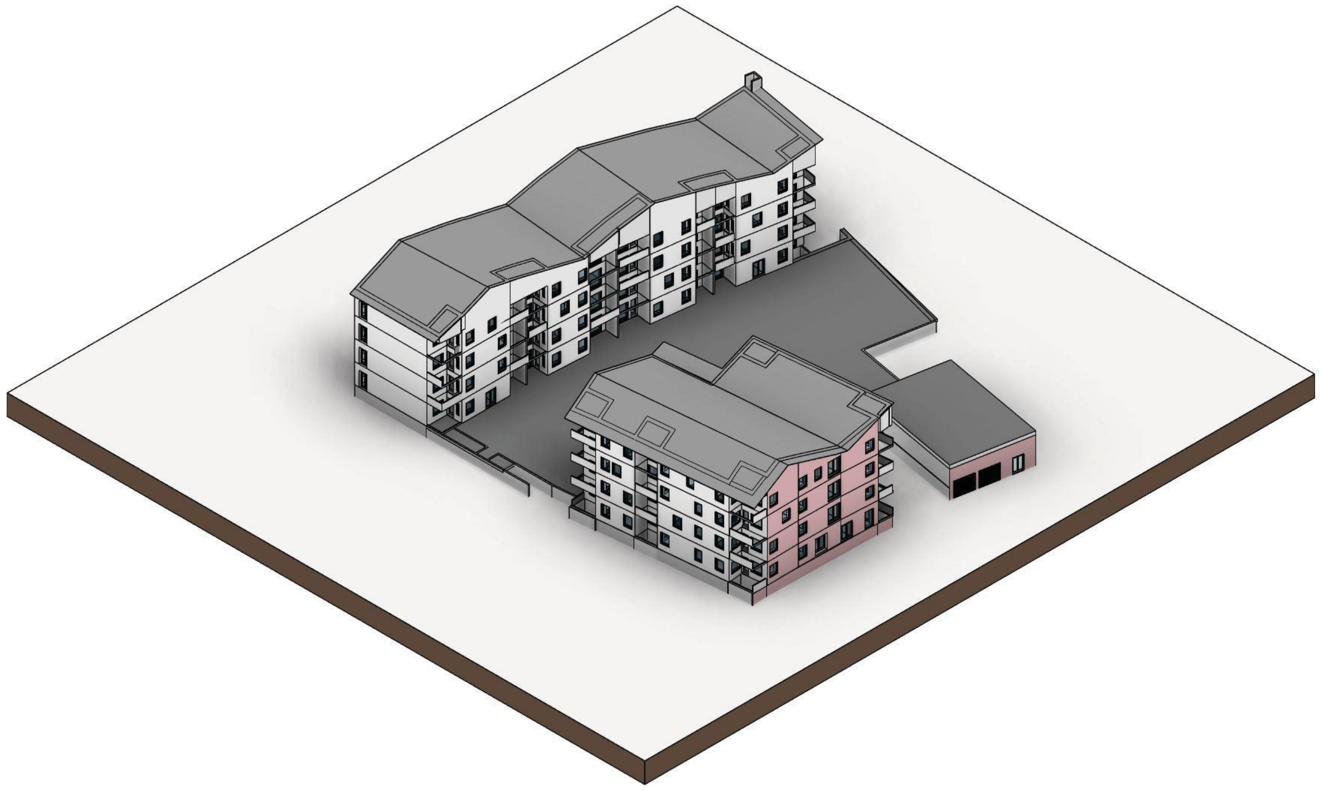


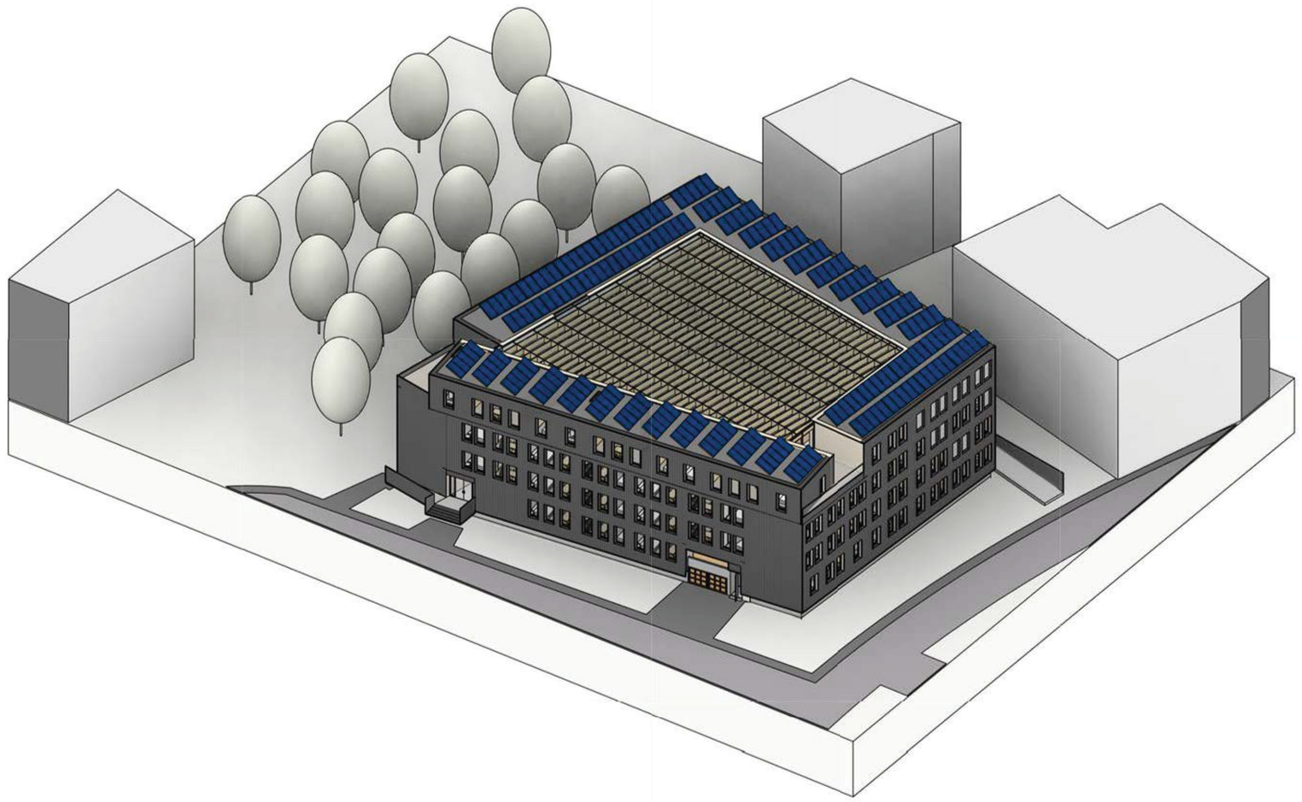
Roof constructions R-3

25 mm	Wood deck
50<150 mm	Ventilated cavety with wooden battens
1 mm	Woood deckWaterproof membrane Derbipure
18 mm	Plywood
150>50 mm	Ventilated cavety with wooden battens
50 mm	Woodfiber board
400 mm	I-joists c-c 600 mm with Celulose insulation
200 mm	CLT slab element



3 COMPARING TYPICAL AND ACTIVE APARTMENT BUILDING





BASE DATA	TYPICAL APARTMENT BUILDING	ACTIVE HOUSE APARTMENT BUILDING
Floor area	Floor area 4100 m^2 + Basement 1800 m^2	Floor area 4800 m^2 + Basement 1700 m^2
External Walls area	External 2850 m^2	External 1900 m^2 + atrium 1600 m^2
Buildings Volume	Heated volume 12 000 m^3	Heated volume 15 300 m^3 + Semi heated volume - 11 700 m^3

COMFORT		
Daylight	Daylight factor = 0,6 % AH below level	Daylight factor = 2 % AH 3 level
Air quality	< 1000 ppm AH 3 level	< 500 ppm AH 1 level
Thermal environment	Better level AH 2 level	Better level AH 1.5 level
ENERGY		
Energy demand	Energy demand 74.2 kWh/m^2 AH 2 level	Energy demand 39.3 kWh/m^2 AH 1 level
Energy supply	Energy supply 4 kWh/m^2 AH 4 level	Energy supply 34.0 kWh/m^2 AH 1.5 level
Energy	Primary Energy 64.2 kWh/m^2 AH 4 level	Primary Energy - 4.7 kWh/m^2 AH 1 level
ENVIRONMENT		
Sustainable construction	Sustainable construction AH below level	Sustainable construction AH 1.5 level
Environmental loads	Environmental loads AH below level	Environmental loads AH 1.5 level
Freshwater consumption	Freshwater consumption AH below level	Freshwater consumption 50 % savings AH 1 level
Conclusion	Good levels in area of Energy and Comfort	Meeting highest Active house standards with reasonable level in Daylight factor

4 Conclusion

The main findings from the thesis are creation of design strategies that strive to meet all Active House radar criteria. The Active House design differs from a typical Finnish multistorey apartment building in some key areas. The New design, compared with the Base project, has improvements in all areas with a specific focus on environmental section and daylighting criteria. All of the strategies discussed in this project could be implemented in other projects across Finland. These were the main design changes in accordance to Active House requirements: increased room ceiling height to 3 m and smaller room depth (up to 6 m) with large windows; external blinds and a semi-heated central atrium; hybrid ventilation system with mechanical heat recovery ventilation units for each apartment; in the atrium of the building located plant boxes and aquaponic gardens provide food for buildings residents; collected rainwater from the roof is used in toilets, shared washing machines, and for watering plants; solar panels are cover all roof areas; materials used in buildings construction have a low or positive environmental impact. Manuals, materials, and tools provided by the Active House Label were a useful guiding material to enact important improvements on a typical Finnish apartment building.

Active House projects are striving towards a balance between the label`s three main, interdependent focus areas – Comfort, Energy, and Environment. From designing this project, I have gained an understanding that the Daylight Factor is the most complex and demanding design criteria, due to the interconnectedness between different focus areas. For example, adjusting the size of the windows to meet the required daylight levels will influence energy performance and environmental impact of the building. Implementing a design strategy in one focus area, will inevitably influence the design as a whole.

The Active House certification system is relatively new, dating back 2016. In order to not complicate the certification system, it incorporates only 9 main certification criteria. During the time of writing this thesis there have already been a few updates that have improved the accuracy of the Active House tools; however, some difficulties still remain. The last update has restricted the user manipulations of the tool calculation logic. Active House Alliance support desk is hard to reach and for a few months their website was not in working order. Nevertheless, with the new updated software (Active House software 1.09 version) and manual (3rd version) they have achieved some welcomed changes. For example, the acoustic values are a part of the evaluation and there has been reconsideration in daylight requirements.

Daylight Factor calculations have been improved in the new release version 1.09. This is an important contribution, since DF is the most design defining criteria, and functionally weakest point of certification up until now. Previous calculations did not take into account occupancy periods. Now it is possible to perform for daylighting Daylight Autonomy (DA) calculation that takes into account room occupancy, and the sky used in the simulations is climate based. Even though Daylighting calculation has improved it is not perfect. DA calculation considers only time period of illuminance of 300 lux or more for the calculation. However, some tasks like working on the computer require daylighting level of 200 lux. The DA calculation even 295 lux is considered as insufficient lighting. Instead of DA calculation it would be better to use other calculation methods. Useful daylight illuminance (UDI) or Continues daylight autonomy (CDA) both are better calculation methods that consider daylight levels that are below 300 lux in their calculations.

Active House design principles could be considered site-specific because buildings` shape corresponds to surrounding context and site boundaries. However, there is still room for improvement, as the Active House tools do not take into account views from the windows, variations in apartment layouts, project budgets, and technical specifics of construction disassembly for future reuse.

The recent update has solved the error in Life cycle analysis. Version 1.4. had some human calculation error that generated wrong results. In current version 1.5 this problem is fixed but there is still a limited number of constructions that the user can create for a simulation; therefore, even the 1.5 version is hard to use in complex projects.

Furthermore, I believe that some design values should be adjusted. There should be more gradual division between energy consumption requirements and sustainable construction requirements. In both areas it is easy to fulfill minimum requirements but hard to meet the maximum demands. Currently, the Active House certification system does not have label gradation. Therefore, there is a big difference between best performing building and building that barely met all criteria, yet both receive the same certification.

Due to limited import fields, daylight requirements, and human calculation errors in software this certification method is difficult and, in some cases, even impossible to apply for apartment building design.

The Active House software is designed with private residential buildings in mind and it is cumbersome to use it for calculations of large-scale projects. Many of the Active House Tools are designed for manual value import and have no access to calculation formulae, which is suitable only for smaller projects. The Radar tool and Environmental Impact calculation tool have a limited number of fields for imported values. Active House Radar in Daylight analysis has 15 room data import limit and there are similar limits on different construction value inputs in Environmental Impact tool, making this tool more suitable for small to medium scale projects. Furthermore, problematic communication with the Active House staff hinders a wider use of this certification method.

That said Active House Radar and other provided tools are useful during design process, even if the building does not meet Active House Label goals in every single criterion.

Recent trends in architecture exhibit a growing awareness of buildings` performance, environmental aspects, and inhabitant's comfort. This is an indicator that the role of an architect is expanding beyond esthetics and the organization of people`s lives. I believe that to achieve long-lasting and innovative architecture we must work across disciplines. Architects must develop broad knowledge and expertise that allows them to navigate this increasing cross-disciplinary field. Architects or project managers are required to have a basic understanding of buildings performance to be able to make informed decisions. For example, Denmark has developed a special Bachelor program in architectural technology and construction management, that focuses more on building`s performance and technical aspects than on architectural qualities. Some of the architecture companies decide to higher architects with a more technical and building science skillset. Leading architecture firms serve as a good example of cross-disciplinarity. To achieve innovation in architecture they look in other fields for inspiration and expertise. Some examples could be found in 3xn, BIG, Zaha Hadid architects work.

With an increasing demand for high-performance buildings, architects will be required to implement performance driven design. Building regulations are demanding better energy performance from new constructions, investors often want to ensure new developments quality standards, and new house owners are more concerned about the environmental impact of their homes. Often architects are preoccupied with design alone without analyzing the building's performance, and only in design last stages involving engineers that somehow need to meet code requirements. I believe that Active House Label is addressing current architectural demands to a great extent. The building`s performance simulations and passive strategies, which Active House Label incorporates, should be considered as an intrinsic part of the design process from the beginning stages.

5 LIST OF FIGURES.